8 Forces in action

The way in which objects move depends on what forces are acting on them. A force is a push or a pull. While you are reading this, the muscles in your eyes are pulling the lenses in your eyes into the right shape so that the words are not blurry.

They say that 'what goes up must come down'. But when a bungee jumper's head is about to reach the water, it should be 'what goes down should come up'.

OVERARCHING IDEAS

- Patterns, order and organisation
- Form and function
- Stability and change
- Scale and measurement
- Matter and energy
- Systems

SCIENCE UNDERSTANDING

Change to an object's motion is caused by unbalanced forces acting on the object

Elaborations

Investigating the effects of applying different forces to familiar objects

Investigating common situations where forces are balanced, such as stationary objects, and unbalanced, such as falling objects

THINK ABOUT FORCES

- Why doesn't gravity make you fall through the floor?
- How does a compass work?
- Why do you sometimes experience a small electric shock when you get out of a car?
- What causes lightning?
- How do crickets make their chirping sound?
- Why is it difficult to walk on ice?
- Why are bicycle helmets necessary?
- What force allows water spiders to walk on the surface of a pond?
- How does a seatbelt protect you in a car accident?

YOUR QUEST

Why don't you fall through the floor?

What force causes the bungee jumper to fall? What makes the jumper slow down before reaching the water? Think about the bungee jumper pictured and answer the following questions.

THINK

1 What is the largest force acting on the jumper just before he reaches the water?

2 Just after the bungee jumper leaps and before the rope tightens, there are two forces acting on him. One is much larger than the other. What are the forces and in which direction does each of them act?

Stand up and think about the forces that are pushing or pulling on you and answer the following questions.

THINK

3 What is the name of the force that is pulling on you now?

4 What force is pushing upwards on your body while you are standing still?

5 What is the size of the upward force compared with the pulling force? How do you know?

INQUIRY: INVESTIGATION 8.1

Water drops

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

Equipment:

5-cent coin

small beaker of water

eye dropper

dishwashing detergent

- Guess how many drops of water you can get onto a five-cent coin before it starts spilling over the edge.
- With great care, and from a very small height, use an eye dropper to place one drop at a time onto the coin. Keep count of the number of drops.
- Dry the coin thoroughly and try again to see whether you can improve on your first attempt.
- Compare your result with those of others in your class.
- Repeat this challenge using water with a few drops of dishwashing detergent added to it.

DISCUSS AND EXPLAIN

1 What is the greatest number of drops that you were able to place on the coin and how does the number compare with your guess?

2 What was the greatest number of drops placed on a five-cent coin in your class?

3 What seems to hold the water on the coin?

4 What difference does adding detergent make to your results?

5 Why do you think the detergent has changed the result?

8.1 SCIENCE UNDERSTANDING

On the move

When a tennis ball is hit with a tennis racquet, it is clear that a **force** is acting on the ball. The ball not only changes its direction of movement, but also, while in contact with the racquet, changes its shape as well.

A force is a push or a pull. Forces are acting around you all the time and they can cause changes to occur. Sometimes the effects are obvious and sometimes they are not. At this moment, forces are acting inside your body to pump blood around. When you write, you use a force to push the pen or pencil.

INQUIRY: INVESTIGATION 8.2

What can a force do?

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

Equipment:

rubber band	*plasticine*
tennis ball	*coin*
plastic ruler or rod	*nylon or wool cloth*

- Copy the table below into your workbook and write down your observations.
- Take note of any changes in the motion or shape of each object and what caused the change in the motion or shape.

DISCUSS AND EXPLAIN

1 When you squash a lump of plasticine and stretch a rubber band, a change in shape is observed. What is different about the behaviour of these two materials?

2 Does the tennis ball change its shape at all when it hits the ground? What would happen to a falling lump of plasticine when it hits the ground? Would it bounce? Check your prediction.

3 Which two of the forces that you observed were able to change the motion of objects without making contact with them?

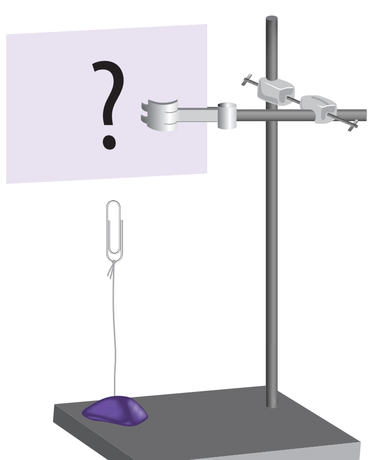
	Observations	
What to do	Changes in motion or shape	What caused the change
Stretch a rubber band.		
Squash a lump of plasticine.		
Push down on the floor with one foot.		
Drop a tennis ball. Observe what happens: (a) at the moment that you drop it (b) as it falls (c) as it hits the ground (d) as it goes up again.		
Flick a coin with one finger so that it slides along the surface of a table. Observe what happens after the coin is flicked.		
Charge a plastic ruler or rod by rubbing it with a nylon or wool cloth. Hold it close to a thin stream of tap water.		

Contact or no contact?

The changes in motion illustrated at right are all caused by **contact forces**. One object is in contact with another. The golf club strikes a ball (and the grass and soil), the air pushes against the parachute to slow down the car and the tube of toothpaste is squeezed to change its shape and push out the toothpaste.

But the motion and shape of objects can be changed without touching them with anything.

When you drop a tennis ball, it speeds up as it falls through the air. The force of **gravity** pulls it towards the Earth. Gravity is a **non-contact force**. An object does not have to be touching the Earth to be pulled towards it. Other forces that can work without touching are **magnetic forces** and **electrostatic forces**.



What is behind the card? (A force must be holding the paperclip in the air.)

WHAT DOES IT MEAN?

The word *gravity* comes from the Latin word ***gravitas***, meaning 'heaviness'.

Magnets can attract each other or some metals, such as iron, from a distance. If you rub a pen with a cloth, you can pick up small pieces of paper with an electrostatic force.

More than one force

Almost never is there only one force acting on an object. You are probably sitting on a chair right now. What forces are acting on you and your chair? There must be at least one! The force of gravity is pulling you towards the centre of the Earth.

If gravity were the only force acting on you and your chair, what would happen to you?

There are four major forces acting on the car pictured at the top of this column: gravity (down), the upward push of the ground, drag provided by the parachutes (to the left) and friction provided by the road on the tyres (to the left if the brakes are applied). The downward and upward forces balance each other out — otherwise the car would rise into the air or sink through the road. There is no force to the right while the driver is braking. The total force is to the left, causing the car to slow down. Without the parachutes it would not slow down quickly enough.

Representing forces

Arrows can be used to represent the sizes and directions of forces. The length of the arrow shows how large the force is compared with another force. The arrows representing forces are usually drawn from the object's centre of gravity. This is where all of the weight of an object would be concentrated if it were in one place. Your body's centre of gravity is at about bellybutton height when you are standing.

The arrows in the photographs on the next page show that the upward and downward forces on the kayaker are the same size but in opposite directions. Gravity pulls the kayaker down and the water pushes the kayak (and the kayaker) up. (The upward push of the water is called buoyancy.) These two forces on the kayaker add up to zero and so there is no change in his upward or downward motion.

The horizontal arrows show that the forward force on the kayaker (provided by using the paddle) is larger than the backward force (provided by the drag of the water). The forward force is larger than the backward force and so the kayaker and kayak speed up. This could not keep happening for long because, as the kayak speeds up, the water drag increases. When the drag reaches the size of the forward force, the total force is zero and the kayak stops speeding up. To speed up again, the kayaker would have to paddle harder or faster.

UNDERSTANDING AND INQUIRING

REMEMBER

1 What is a force?

2 List six ways in which a force can affect an object.

3 Which of the following are non-contact forces: friction, electrostatic force, magnetic force, gravity?

4 Name the force that opposes the movement of an object through water.

THINK

5 Copy the following table into your workbook. Complete it by thinking of two or three everyday examples of each of the effects of forces. You can complete your table with diagrams or words.

Everyday effects of forces

Effect	Examples in everyday life
Starting motion	
Stopping motion	
Speeding up motion	
Slowing down motion	
Changing the direction of motion	
Changing the shape of an object	
Having no visible effect	

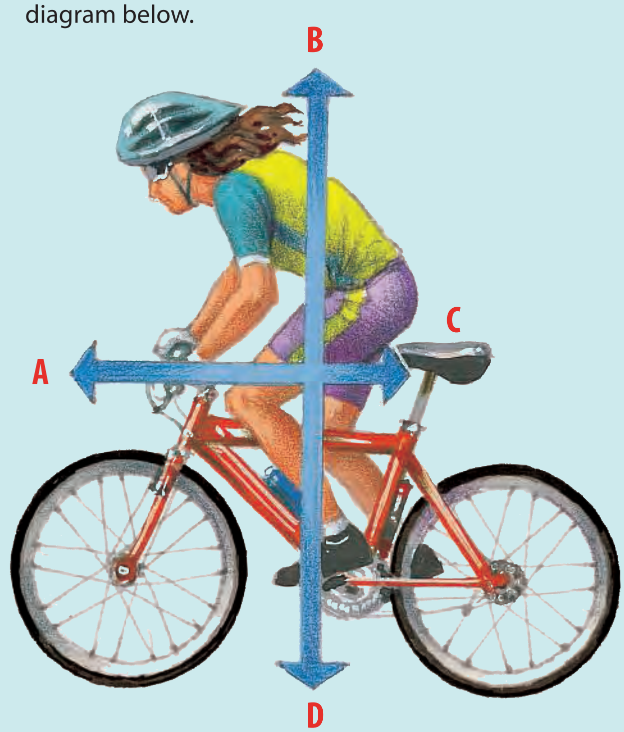
6 When you flick a coin so that it slides across a table, it slows down.
  (a) What is the name of the force that slows it down?
  (b) While your finger is still pushing the coin, there are four forces acting on the coin. What are they? Draw a diagram with arrows showing the direction in which each of the four forces pushes or pulls.
  (c) How many forces are acting on the coin after your finger stops pushing?

7 Explain why you don't fall through the floor.

8 Is drag a contact or non-contact force? Explain your answer.

9 Where would you expect to find the centre of gravity of a plastic ruler?

10 There are four forces acting on the person in the diagram below.



  (a) Which of the four forces represented is a non-contact force?
  (b) What would happen if forces B and D were not equal?
  (c) Is the cyclist's speed increasing, decreasing or remaining steady?
  (d) Describe what would happen to the cyclist's motion if the size of force C increased to become equal in size to force A?
  (e) What would happen if force C became greater in size than force A?

8.2 SCIENCE UNDERSTANDING

A magnetic attraction

Make a list of all the things that you come into contact with every day that use magnets. The pictures below will give you some clues. Share your ideas with others and compile a class list.

Magnets can attract certain materials without actually touching them. Magnetic forces can therefore be referred to as non-contact forces.

Magnets that retain their magnetism when removed from other magnets are called **permanent magnets**. Natural permanent magnets contain one or more of the elements iron, nickel and cobalt. The most common natural permanent magnetic substance is magnetite, also known as lodestone.

Magnets that might be found at home: fridge magnets, a cupboard door latch, a magnetic knife holder and a magnetic screwdriver

Most permanent magnets, however, are **alloys**, or mixtures, of iron, nickel or cobalt with other elements or each other. Items made of steel are attracted to magnets because steel is an alloy of iron, carbon and other substances.

Temporary magnets are those that lose their magnetism when removed from another magnet. The paperclips in Investigation 8.7 are temporary magnets while in contact with the permanent magnet. As soon as they are removed from the electromagnet, they lose their magnetism.

INQUIRY: INVESTIGATION 8.3

What does a magnet attract?

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

Equipment:

magnet

selection of materials to be tested (see the list at right)

- Place a magnet close to a range of materials to find out which ones are attracted to it. Record your observations in a table like the one below.

Attracted	Not attracted

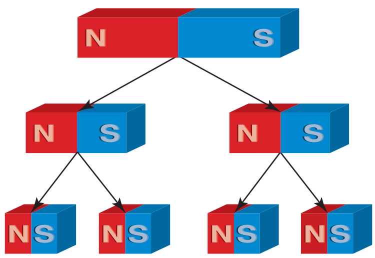
- Test as many of the following items as possible: pencil, paper straw, plastic straw, coins, iron nail, stainless steel spoon, aluminium foil, paperclip, copper wire.
- Do some materials 'block' the magnetic force? Design an experiment to find out.

DISCUSS AND EXPLAIN

1 Which materials were attracted to the magnet?
2 Are all metals attracted to magnets?
3 Of the materials that were attracted to the magnet, which one was attracted the most? Why do you think this was so?
4 Were any forces other than the magnetic force acting on the objects? If so, what were they?
5 Were there any unexpected observations? If so, what were they?

Magnetic poles

All magnets, no matter what their shape, have a **north pole** at one end and a **south pole** at the other. When a magnet is cut in half, each half still has a north pole and a south pole. If you keep cutting a magnet in half over and over again, each half always has a north pole and a south pole.



Magnets always have a north pole and a south pole, even if broken in half.

INQUIRY: INVESTIGATION 8.4

Poles apart

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

2 bar magnets

- Take two bar magnets and identify the north and south pole of each. Position the magnets near each other as shown below. Take note of whether the magnets attract or repel each other in each case.

  (a) | N | S |

  (b) | N | N |

  (c) | S | S |

  (d) | S | N |

  Attraction or repulsion?

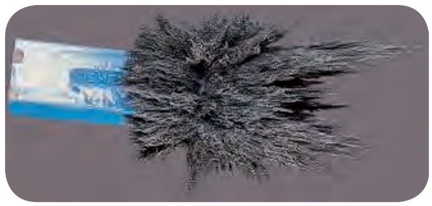
- Complete the sentences to form your conclusion:

  Like poles ____________.

  Unlike poles ____________.

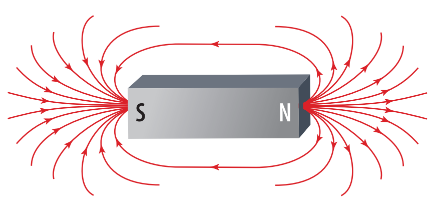
MAGNETIC FIELDS

Each of the tiny iron filings in the photograph below is attracted to the magnet. The filings line up in the direction of the magnetic force around the magnet. The area where the magnetic force acts is called the **magnetic field**.



Iron filings sprinkled around a bar magnet

The magnetic field can be drawn like a map, as in the diagram below. The lines show the direction of the magnetic force. The lines are closest together where the magnetic force is greatest and furthest apart where the magnetic field is weakest. Notice that the lines of the magnetic field point away from the north pole and towards the south; that is, from north to south. The north pole of a compass points in the direction of a magnet's magnetic field.



Magnetic fields can be drawn as maps.

THE EARTH'S MAGNETIC FIELD

When a bar magnet is suspended by a string at its centre, it always lines up with the North and South Poles of the Earth.

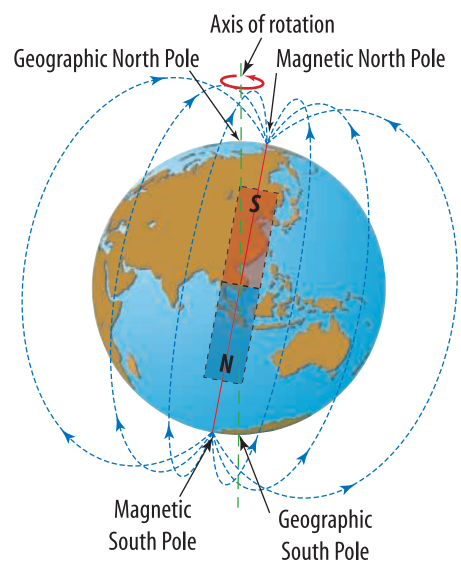
The Earth, like the sun and some planets, has its own magnetic field. It is very much like the magnetic field of a bar magnet. Scientists are not sure why the Earth has a magnetic field.

Any magnet free to turn will line itself up along the field lines. The north pole of the magnet is the pole that points towards the North Pole of the Earth. In a similar way, the south pole of a magnet points towards the South Pole of the Earth.

A compass is just a small magnet with its poles tapered to a point. The north pole of a compass is usually coloured; so the coloured end of the compass points towards the North Pole of the Earth. However, if another magnet is brought close to a compass, the north pole of the compass points towards the south pole of the other magnet.

The direction of any magnetic field is the direction in which the north pole of a compass needle points.

Notice that there are two north poles and two south poles shown on the diagram of the Earth. The Magnetic North Pole is about 1000 km from the Geographic North Pole and the Magnetic South Pole is about 1000 km from the Geographic South Pole. Both magnetic poles move about 40 kilometres every year.



The Earth's magnetic field

INQUIRY: INVESTIGATION 8.5

Mapping the magnetic field

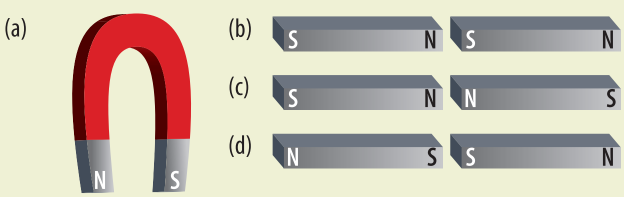
KEY INQUIRY SKILLS:

- processing and analysing data and information
- communicating

Equipment:

horseshoe magnet in a plastic bag
overhead transparency
2 bar magnets in plastic bags
sheet of A4 paper
iron filings
small compass

- Place a bar magnet in the centre of a sheet of white paper. Cover the paper and magnet with an overhead transparency.
- Carefully sprinkle iron filings over the transparency, gently tapping it to spread the filings out. Take care not to let iron filings get under the transparency.
- Draw a diagram of the pattern made by the iron filings. Label the north pole and south pole of your magnet on the diagram. The pattern in your diagram is a map of the magnetic field around the bar magnet.
- Use the iron filings to investigate the magnetic fields around a horseshoe magnet and the pairs of magnets shown in the figure below.



Use the iron filings to investigate the magnetic fields around these magnets.

DISCUSS AND EXPLAIN

1. Where does the magnetic field appear to be strongest? How do you know this?
2. What happens to the strength of the magnetic field as you get further from the magnet?
3. Place a compass at several positions around the magnet. The direction in which the compass needle points shows the direction of the magnetic field lines. Add arrows to your diagram to show the direction of the magnetic field.
4. Do the magnetic field lines run from north pole to south pole or from south pole to north pole?
5. Draw a diagram of the magnetic fields around the magnets in the figure above. Use your compass to help you decide which way the arrows should go on your diagram.

INQUIRY: INVESTIGATION 8.6

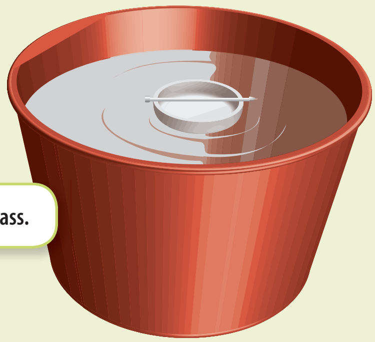
Making your own compass

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

large iron nail (about 75 mm long)
strong magnet
paperclips or small nails
sewing needle



Make your own compass.

- Take a large iron nail and stroke it with a strong permanent magnet. After each stroke, lift the magnet high above the nail before commencing the next one. You need to make sure that each stroke is in the same direction and made with the same end of the magnet.
- After a total of 40 strokes, test your new magnet by trying to attract paperclips or small nails.
- Compare the strength of your magnet with that of others in your class.
- Use your magnet to make a compass like the one shown above. You will need a container of water and a float. The bottom of a styrofoam cup will make a good float.
- Try dropping your 'homemade' magnet on the floor. Test it to see if it works.
- Try to magnetise a sewing needle instead of an iron nail.

DISCUSS AND EXPLAIN

1. Is your magnet a permanent magnet or a temporary magnet?
2. Which end of your magnet is the north pole? How do you know?
3. Could you magnetise the sewing needle? Explain why or why not.

Switched on magnets

An electromagnet is a coil of wire wrapped around an iron core. When an electric current is passed through the coil, the iron is magnetised. When the current is turned off, the iron is no longer magnetised. Being able to turn a magnet on and off at will can be very useful.

HOW ABOUT THAT!

The coil of wire that is wrapped around the iron core in an electromagnet is called a solenoid. Even without the iron core inside, a solenoid produces a magnetic field. Solenoids are used in many devices, including cars, to switch things on and off.

The photograph on the right shows one such use. The electromagnet is attached to a giant crane. The electric current is turned off while the electromagnet is lowered onto the load of scrap metal to be lifted. When the current is switched on, the iron or steel in the scrap is attracted to the electromagnet and lifted to a container. The electric current is switched off and the metal falls into the container. However, if the metal was not mostly iron or steel, the electromagnet would be of little or no use.

Electromagnets like the one in the photograph are also useful in separating iron and steel from other scrap metal. The scrap metal is first shredded into small pieces.

Electromagnets are also used in doorbells, metal detectors, speakers, phones, electric motors and generators.

Amazing magnets

We use electromagnets and permanent magnets every day. Computer hard drives store information by forming magnetic patterns on disks. Electromagnets are used to store and read the magnetic patterns. Phones have microphones and speakers that rely on both permanent magnets and electromagnets. iPods and mp3 players have speakers with electric motors and generators that utilise magnets. Metal detectors and many doorbells also contain electromagnets.

INQUIRY: INVESTIGATION 8.7

Making an electromagnet

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

Equipment:

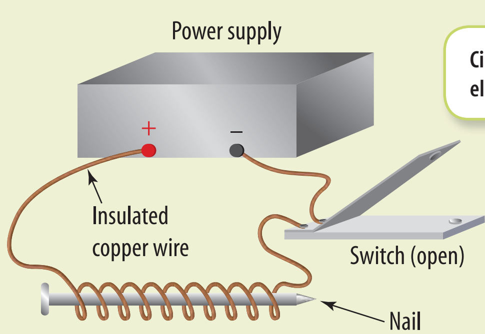
2 insulated wires, one short, the other 1.5 m long

power supply

switch

paperclips (many)

- Set up the electric circuit as shown in the diagram below.



Circuit for an electromagnet

- Wind 15 turns of the longer wire around the nail. There will be a lot of wire left over but do not cut it.
- Set the power supply to 2 volts and close the switch.
- Test your electromagnet by opening the switch and seeing how many paperclips it will pick up.
- Record your results in a table like the one below.
- Wind five more turns of wire around the nail.
- Record the number of paperclips picked up by your electromagnet now.
- Keep winding the wire around the nail. Record the number of paperclips picked up by 25 and 30 turns of wire.
- Increase the voltage to 4 volts and repeat the previous steps.

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	

DISCUSS AND EXPLAIN

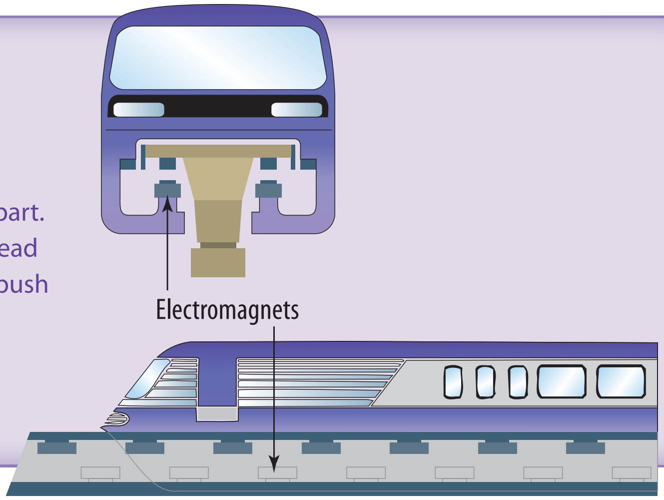
1. What is the effect of increasing the number of turns around the nail?
2. What is the effect of increasing the voltage?
3. Did the iron nail retain its magnetism when the current was switched off? Explain.

HOW ABOUT THAT!

The maglev train gets its name from MAGnetic LEVitation. It reaches speeds of up to 500 km/h and doesn't even need a normal engine to run! It uses pushing forces between electromagnets on the track and on the train to keep them apart.

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

The maglev train seems to float above the train tracks. The train touches the track only while it is building up speed before moving.



UNDERSTANDING AND INQUIRING

REMEMBER

1 Which of the following statements is correct?
(a) Permanent magnets never lose their magnetism.
(b) All metals are strongly attracted to magnets.
(c) Iron, steel and nickel are attracted to magnets.
(d) Iron is the only substance attracted to magnets.

2 What is the difference between a permanent magnet and a temporary magnet?

3 How should two bar magnets be placed on a table so that they repel each other?

4 What is a magnetic field?

5 How is the direction of a magnetic field determined?

6 Describe what an electromagnet is and explain how it works.

7 List some everyday devices that use electromagnets.

THINK

8 Make a list of as many items as you can that are, or contain, permanent magnets.

9 The North Magnetic Pole of the Earth can be considered as one pole of a bar magnet. Is it a south pole or a north pole? Explain your answer.

10 Which way would the coloured end of a compass point if you were in a plane flying directly above the Earth's North Magnetic Pole?

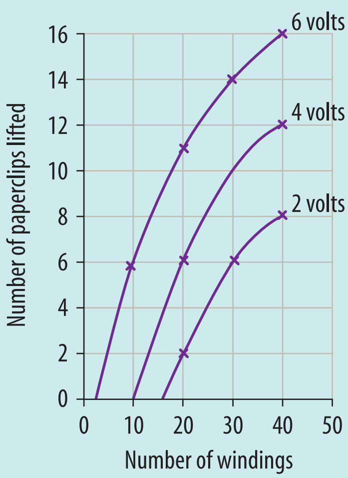
11 What is the advantage of an electromagnet over a permanent magnet? Use an example to illustrate your answer.

12 Explain why people are advised to keep strong magnets away from computer hard drives.

13 Explain how the maglev train is able to travel so fast.

ANALYSE

14 Arianna made her own electromagnet to find out how the number of windings around a nail affected the number of paperclips that the nail could pick up. She used the circuit shown in Investigation 8.7 with the power supply set to 2 volts. Arianna then repeated her measurements with the power supply set to 4 volts and 6 volts. She recorded her observations in a table, then she constructed a graph (above).



(a) How many paperclips did Arianna lift with 20 windings and the power supply set to 6 volts?
(b) Arianna lifted 12 paperclips when the power supply was set to 4 volts. How many windings were there around the nail?
(c) How many paperclips could Arianna expect to lift with 50 windings around the nail and the power supply set to 2 volts?
(d) Suggest a way in which Arianna would be able to make her results more reliable.

EXPLORE

15 Design and carry out an experiment to measure the strength of different magnets. Record your measurements in a table and display them using a bar or column graph.

CREATE

16 Build a device that uses an electromagnet to make a noise when you close a switch or push a button.

work sheet 8.1 Magnetic words

All charged up

The girl in the photo has her hand on a Van de Graaff generator. It was invented in 1929 and was used to smash **atoms** to find out more about them.

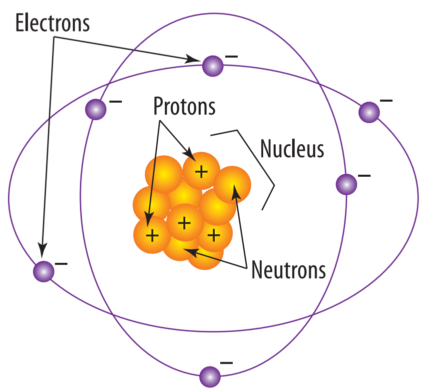
The girl is obviously 'all charged up'. The force pushing her hair úp is called an electrostatic force. To understand electrostatic forces, we need to have a look inside the atom.

What it means to be charged

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

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

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



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

Getting charged

Substances usually become charged by the addition or removal of electrons. This can be done in two ways: by friction or by contact.

FRICTION

The rubbing of one neutral substance against another adds or removes electrons. When you rub a plastic ruler with wool, electrons are moved from the neutral wool onto the neutral plastic ruler. The wool, having lost electrons, becomes positively charged. The plastic ruler, having gained electrons, becomes negatively charged.

CONTACT

If a neutral substance is touched by a charged object, electrons can move to or from the charged object. When the charged object is removed, the previously neutral substance has gained or lost electrons. The girl touching the dome in the photograph on the left would became charged by contact, having lost electrons to the dome. Her hair stands on end, repelled from the rest of her positively charged body.

Electrons are the easiest particles to add to or remove from atoms, because they are not held together in the nucleus as protons are.

eBook*plus* **eLesson**

Producing static electricity

Learn about static electricity and watch it being produced by charging perspex and ebonite rods.

eles-0067

Standing still

The electricity that builds up on plastic rulers, balloons and the Van de Graaff generator is called **static electricity**. The word 'static' means standing still. The charge on the objects is called electrostatic charge (or static charge). Static charge can leak slowly through substances such as rubber and air. Substances through which electric charge cannot move quickly are called **insulators**. Static charge builds up easily in insulators. Substances through which electric charge flows easily are called **conductors**. Metals are good conductors of electricity. Static charge doesn't build up in conductors.

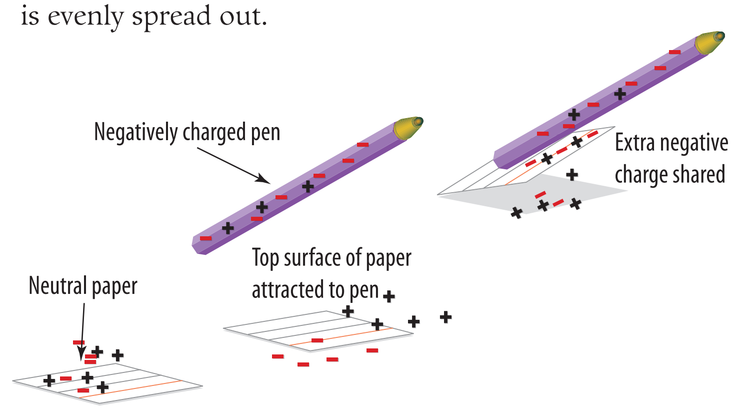
Objects with the same static charge repel each other while those with opposite charges attract each other. If sufficient charge builds up in oppositely charged objects, the attraction between the electric charges is so great that they can jump across small air gaps. Lightning is caused by the movement of electric charge between a cloud and the ground. However, the clouds and ground are both neutral! Lightning seems to show that electric charge can move between neutral objects as well as between oppositely charged objects. The explanation for this can be found on the right.

But it wasn't charged!

Charged objects and neutral objects can be attracted to each other. A charged plastic pen attracts a neutral stream of water. A charged balloon sticks to a neutral wall. A charged comb will make dry hair stand up. The illustration on the right shows how a negatively charged plastic pen is able to pick up a small, neutral piece of paper.

Only a few charges have been labelled in the illustration. In reality there would be millions and millions of them. The labelled charges are there to show whether an object is neutral or charged, and how the charge is arranged in the object.

When the negatively charged pen is close to the paper, electrons are repelled from the pen, leaving the top surface of the paper with a positive charge. Note that the whole piece of paper is still neutral. If there is enough charge and the pen is close enough to the paper, the attraction is great enough to pull the paper up. Once the paper is touching the pen, the charge moves across and arranges itself so that it is evenly spread out.



Charged and neutral objects can be attracted to each other.

INQUIRY: INVESTIGATION 8.8

The attraction of electricity

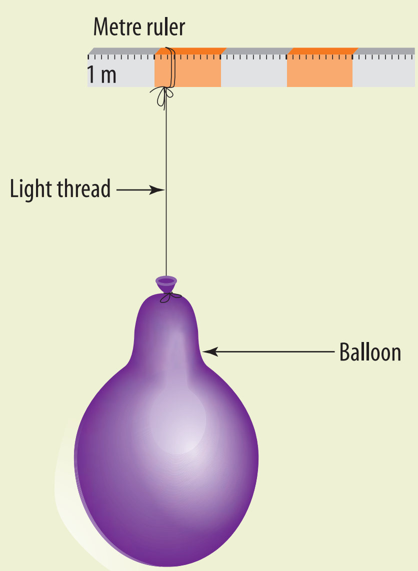
KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

2 balloons | *light thread*
woollen cloth | *metre ruler*

- Suspend one balloon from the metre ruler with light thread, as shown in the diagram.
- Rub the balloon with a woollen cloth.
- Remove the woollen cloth and then place it close to, but not touching, the part of the balloon that was rubbed. Observe any movement of the balloon.
- Suspend a second balloon from the metre ruler so that it is close to, but not touching, the first balloon.
- Rub each of the balloons with a woollen cloth — rub on the surfaces that are facing each other.



Suspend a balloon from a metre ruler.

- Remove the cloth and position the balloons so that they are as close together as they can be without touching each other. Observe any movement of the balloons.

DISCUSS AND EXPLAIN

1. Describe the movement of the single balloon.
2. Do the balloons have the same charge as the woollen cloth after they are rubbed?
3. Describe the movement of the balloons.
4. After being rubbed with the woollen cloth, do the balloons have like or unlike electric charges?
5. Copy and complete the following sentences by choosing the correct word from the pair of underlined words.

- Objects with like charges <u>attract/</u> <u>repel</u> each other.
- Objects with unlike charges <u>attract/</u> <u>repel</u> each other.

INQUIRY: INVESTIGATION 8.9

Defying gravity

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

plastic ballpoint or felt-tip pen
woollen, cotton or nylon cloth
balloon

- Rub a plastic pen with a piece of cloth, then hold it near a thin stream of water from a tap. Observe the behaviour of the water.
- Rub an inflated balloon with the woollen cloth and place it against a wall.
- If the balloon does *not* stick to the wall, try rubbing it with a different type of cloth.

DISCUSS AND EXPLAIN

1. Describe what happened to the water.
2. Did the balloon stick to the wall?
3. Explain the behaviour of the water and balloon in your own words.
4. What is the effect of the cloth on the balloon?

Static charge — what a nuisance!

- When you clean and polish windows and mirrors with a cloth you leave the surface with an electric charge. The light, neutral dust particles nearby are attracted to the surface in the same way that the paper is attracted to the pen. Similarly, TV and computer monitor screens attract dust while they are being used.
- When you walk on carpet, the friction between the surface and your shoes gives your body an electric charge. If the air is dry and you are wearing rubber-soled shoes, the charge does not leak away and builds up. When you touch a metal object such as a door handle, the charge moves very quickly to or from your body, causing a small electric shock.
- A moving car builds up static electric charge as its tyres move along the road and its body rushes through the air. Because its driver and passengers are in contact with the car, they share the electric charge that builds up. Sometimes you will get a small electric shock when you get out of the car and touch the metal body, because the charge moves through your body to the ground.

When lightning strikes

The particles of water and ice inside clouds are constantly moving and colliding with each other. When they collide, electrons are transferred from the smaller particles to the larger particles. This leaves the lighter, smaller particles with a positive charge and the heavier, larger particles with a negative charge. Updrafts take the lighter positively charged particles closer to the top of the cloud. The larger negatively charged particles fall towards the lower part of the cloud.

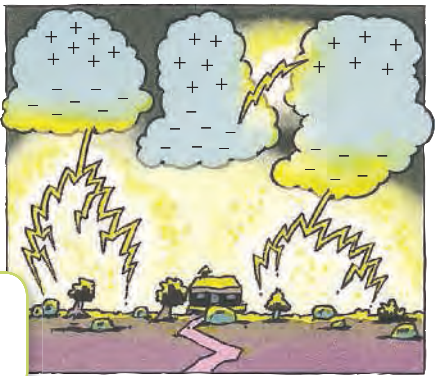
The charges keep building up. Eventually there is so much charge built up that huge numbers of electrons move from the lower part of the cloud to either the upper part of a neighbouring cloud or the ground.

If a bolt of lightning 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 tops 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.

When static electricity is useful

Static electricity is not always a pest. For example, photocopying machines use static electricity to make copies. Electrostatic speakers are used with some stereo equipment. Electrostatic attraction can be used to separate light particles from other substances. In a chimney, smoke particles are charged as they move past a metal grid. They are then attracted to the sides of the chimney and form a layer of soot instead of passing out to pollute the air.



Lightning is caused by the movement of charge between neutral objects.

HOW ABOUT THAT!

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 operating theatres use gases that could easily explode. 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 makes 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.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Which two particles of an atom carry electric charge? Which type of electric charge does each of these particles carry?

2 Which particle of an atom carries no electric charge?

3 When you rub a plastic ruler with a woollen cloth, the plastic ruler becomes negatively charged.
   (a) What happens to the atoms in the cloth and ruler to cause this change?
   (b) Complete the sentence. As the ruler becomes negatively charged, the cloth becomes ___________ charged because it has more___________than electrons.

4 Complete each of the following sentences by using the words 'attract' or 'repel'.
   (a) Two positively charged objects would be expected to ___________ each other.
   (b) Two negatively charged objects would be expected to ___________ each other.
   (c) A positively charged object would be expected to ___________ a negatively charged object.

5 Explain, with the aid of a diagram, how it is possible for a neutral object to be attracted to a charged object.

THINK

6 In the diagram of the carbon atom on page 273, some of the protons are not visible. How many are hidden by other protons?

7 Two balloons are hanging on threads next to each other, but not touching. They begin to move away from each other. If one of the balloons is positively charged, what is the charge of the other balloon?

8 Explain why a student who planned to touch the dome of a Van de Graaff generator (shown in the photograph on page 273) might be wearing rubber-soled shoes and standing on a plastic mat.

9 A plastic spoon that has just been dried with a tea towel is placed near some pepper spilt on a kitchen bench. Some of the pepper is attracted to the spoon and sticks to it. Explain why this happens.

10 If you placed a charged pen near a whole A4 sheet of paper, would you expect the paper to rise and stick to the pen? Give a reason for your answer.

11 Draw a labelled diagram to show how a neutral stream of water from a tap is attracted to a charged plastic pen. Use the symbols + and – to represent positive and negative charge.

12 Why are you less likely to get an electric shock after walking on carpet in humid weather than in dry weather?

13 As planes move through the air, they build up large amounts of static electricity. How does this happen? Before refuelling, a wire is used to connect the plane to the ground. Why is this important?

CREATE

14 Devise a model, using people to represent positive and negative charge, to show how objects become positively and negatively charged. Use your model to demonstrate:
   (a) whether a neutral object contains any electric charge
   (b) what must happen to make an object:
      (i) negatively charged
      (ii) positively charged?

INVESTIGATE

15 Can static electricity be used to separate a mixture of salt and pepper? Try it!

16 Have you ever heard a crackling sound when you remove your clothes at night? What causes it? Which types of clothes are most likely to cause the crackling? Once you find out, try removing them in front of a mirror in total darkness and watch for the sparks.

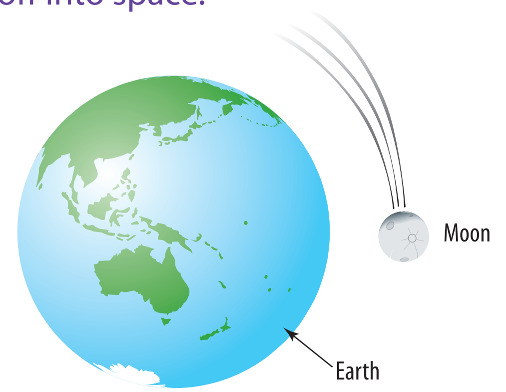
17 Use the internet to explore the link between lightning and ozone. Does lightning increase or decrease the amount of ozone in the atmosphere?

work sheet 8.2 Sticky food

8.4 OVERARCHING IDEAS

Scale and measurement

What causes a ball to fall to the ground after you throw it? Why don't you get flung from the surface of the Earth as it spins around? What keeps the moon in orbit around the Earth and the planets in orbit around the sun? The answer to all of these is the force of gravity. Without the force of gravity, even the Earth's atmosphere would float off into space.



The force of gravity keeps the moon in orbit. Without it, the moon would fly past the Earth.

Gravity is universal

Every object in the universe pulls on other objects with a force of gravity. The force of gravity towards an object depends on its mass. **Mass** is a measure of the amount of material in an object of substance. The mass of an object is the same wherever it is in the universe. The greater the mass of an object, the greater the force of gravity is on it. And gravity is such a tiny force that, unless the object is as large as a star, planet or moon, its pull of gravity is just too small to notice or measure compared with other forces.

WEIGHT AND MASS

The **weight** of an object or substance is a measure of the force of gravity pulling it down towards the centre of a large object such as a planet, moon or star.

The standard unit of force is the **newton** (N). Because weight is a force, it is measured in newtons. At the Earth's surface, the force of gravity is about 10 newtons for every kilogram of mass. So a 50-kilogram person has a weight of about 500 newtons on Earth. On Mars, however, the force of gravity is only about four newtons for every kilogram. A 50-kilogram person would have a weight of only 200 newtons on Mars.

HOW ABOUT THAT!

Isaac Newton (1643–1727) was an English mathematician, physicist, astronomer and philosopher. You might know him as the guy who sat under the apple tree and, after being struck on the head by a falling apple, discovered gravity. But it probably didn't happen that way. Many scientists and historians believe that Newton was looking out of the window when he saw the apple fall.

Whichever way it happened he was struck with a realisation — apples (and everything else) always fall down, not up or sideways. He wondered about the force that caused this to happen. He wondered what would happen if the tree were much taller. In fact, he was able to deduce, after much time and many calculations, that the force that caused the apple to fall was the same force (gravity) that kept the moon in orbit around the Earth. From these ideas, Newton wrote his Law of Universal Gravitation, which describes how gravity acts in all places, not just on Earth.

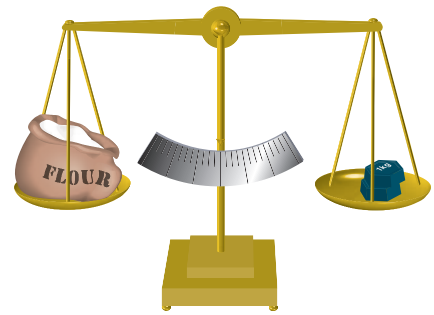
Newton was able to explain many observations, including falling apples, tides and orbiting planets with a single law of gravity.

Measuring mass and weight

Mass is measured with a balance. The illustration on the right shows an old-fashioned measuring scale on which the mass being measured is being compared with a known mass. A two-kilogram pile of flour will balance the two standard kilogram masses no matter what the pull of gravity is.

A laboratory beam balance measures mass by balancing the object to be measured on one side with sliding masses on the other side.

Weight can be measured with a spring balance like the one shown in Investigation 8.11. The weight of the object being measured pulls down on the spring and stretches it. The spring stretches evenly and has a pointer attached to it.



The two-kilogram pile of flour will always balance the two standard kilogram weights.

INQUIRY: INVESTIGATION 8.10

More than one force?

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

Equipment:

20-cent coin

scissors

paper

- Drop a coin from about chest height.

The force of gravity on the coin (its weight) pulls it down. It speeds up until it hits the floor.

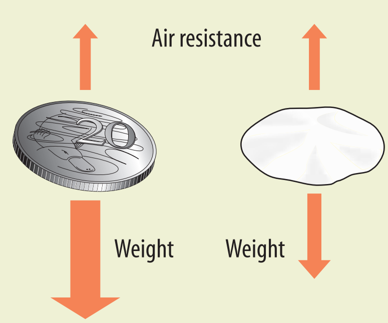
- Cut out a disc of paper about the size of a 10-cent coin. Hold the paper disc in one hand and the 20-cent coin in the other, both at chest height.

Drop the paper disc and coin from chest height at the same time.

- Predict what will happen if you drop them at the same time. Test your prediction.
- Place the disc of paper on top of the coin and drop them together from waist height.

DISCUSS AND EXPLAIN

1. How many forces are acting on the coin as it falls through the air?
2. Which object landed first? Was your prediction correct?
3. What two forces were acting on the paper disc when it was dropped on its own?
4. What is different about the forces acting on the coin?
5. Which lands first when the paper disc sits on top of the coin?
6. When dropped together with the paper disc on top, how are the forces different from the way they are represented below?



The forces acting on a coin and a disc of paper as they fall separately

INQUIRY: INVESTIGATION 8.11

Measuring weight

KEY INQUIRY SKILLS:

- processing and analysing data and information
- evaluating

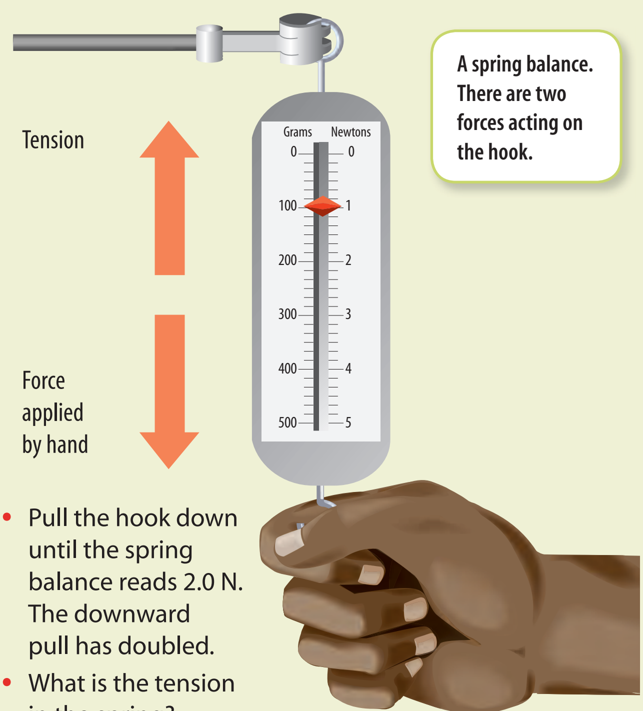
Equipment:

5.0 N spring balance

set of slotted 50 g masses

retort stand, bosshead and clamp

- Pull down on the hook of a 5.0 N spring balance until it reads 1.0 N. There are two forces acting on the hook. As long as the hook is not changing its motion, the upward force of tension is the same as the downward pull of your hand.



A spring balance. There are two forces acting on the hook.

- Pull the hook down until the spring balance reads 2.0 N. The downward pull has doubled.
- What is the tension in the spring?
- What has happened to the amount that the spring has stretched?

A spring is a good force measurer because, if the pulling force on it doubles, the amount of stretch doubles. If the pulling force triples, the amount of stretch triples.

- Hang the spring balance from a rod fixed to a retort stand and adjust the pointer so that it reads zero.
- Attach a 50 g mass to the hook of the spring balance and record its weight in newtons by copying and completing the table above right. Also calculate and record the mass in kilograms by dividing the mass in grams by 1000.
- Add 50 g masses, one at a time, until you have a total mass of 400 g. Record the mass in kilograms and weight in newtons as you go.

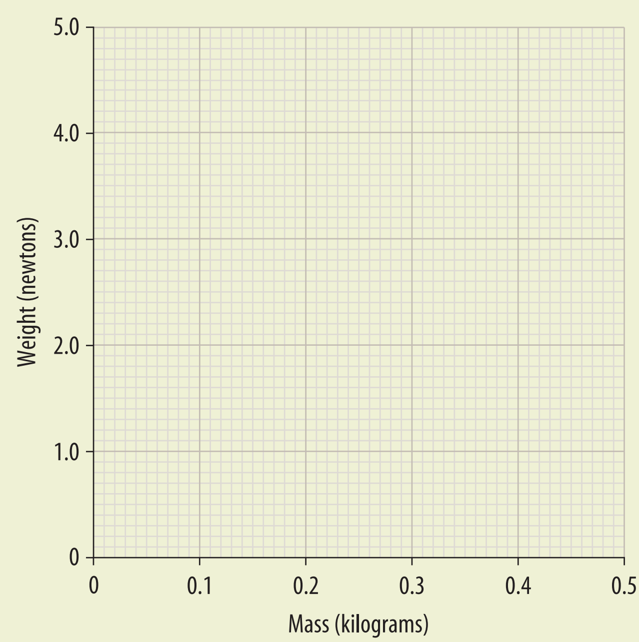
Measuring weight

Mass (g)	Mass (kg)	Weight (N)
50	0.05	
100	0.10	
150	0.15	

DISCUSS AND EXPLAIN

1. Why is it better to hang the spring balance from a rod rather than hold it in your hand?
2. Does the spring increase its stretch by the same amount each time a 50 g mass is added?
3. How would your results be different if you conducted this activity on Mars?
4. Use your results to complete a copy of the graph below.

Graph of weight measured on a spring balance versus mass



5. Draw a line through the points that you have plotted and continue your line to where you think it would be if you measured the weight of a mass of 500 g. This process is called extrapolation.
6. Is your line straight? Should it be straight?
7. What does your graph tell you should be the weight of a 500 g mass? Measure it and see how accurate your prediction is.
8. How could you alter the scale on the spring balance so that you could read the correct mass from it directly?

Falling down

Imagine you are falling through the air with the skydivers in the photograph on the right. What would you feel? You would quickly realise that gravity is not the only force acting on falling objects.

The way objects fall depends on the total force acting on them, not just on the pull of gravity. Air in the atmosphere pushes against all falling objects. This push is called **air resistance**. Air resistance is an example of fluid friction.

When the paper disc is dropped together with the coin in the second part of Investigation 8.10, the coin shields it from the air that would normally push against it.

SPEEDING UP

The air resistance on a moving object increases as the object moves faster. When cycling or running quickly, you feel the air pushing against your face even if there is no wind. When you slow down, you don't feel the same push of air against you.

There is more than one force acting on these skydivers.

INQUIRY: INVESTIGATION 8.12

The landing time of a parachute

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information
- evaluating
- communicating

Equipment:

plastic from freezer bags	*scissors*
large paperclips, or plasticine	*stopwatch*
cotton or nylon thread	*metre ruler*

Your task is to find out the effect of one of the following factors on the landing time of a parachute.

(a) Mass of the skydiver
(b) Size (area) of the canopy
(c) Shape of the canopy

Use plastic from freezer bags to make the canopy. Cotton or nylon thread can be used to hold a model skydiver, which could be represented by paperclips or plasticine.

Ensure that you do each of the following:

- Keep all things constant except the factor that you are deliberately changing, so that your tests are fair. This is called controlling variables.
- Repeat your measurements of time at least three times and work out an average.
- Draw up a table in which to record your results. An example is provided below.

Area of canopy (square centimetres)	Time taken to fall (seconds)			
	Trial 1	Trial 2	Trial 3	Average
$24 \times 24 = 576$				
$21 \times 21 = 441$				
$18 \times 18 = 324$				
$15 \times 15 = 225$				
$12 \times 12 = 144$				

DISCUSS AND EXPLAIN

1 Write a report of your investigation using these headings.
- Aim
- Materials
- Method
- Results
- Discussion
- Conclusion

2 In your discussion, you should evaluate your results and comment on how your design could be improved.

3 As an extra challenge after the investigation has been completed, see who can make the parachute that takes longest to reach the floor with a standard load of five paperclips from a height of two metres.

TERMINAL SPEED

When an object starts to fall, it moves slowly. There is not much air resistance. As the object speeds up, the air resistance increases. If the object travels fast enough, the air resistance can become as great as the force of gravity on the object. Once the air resistance balances the force of gravity, the object stops speeding up. It has reached its **terminal speed**. It won't fall any faster.

WHAT DOES IT MEAN?

The word *terminal* comes from the Latin word ***terminalis***, meaning 'end' or 'limit'.

HOW ABOUT THAT!

Skydivers reach speeds of about 200 km/h before air resistance is great enough to balance their weight. After the parachute has opened, the air resistance is much greater than the skydiver's weight, slowing him or her down to about 20 km/h.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Explain the difference between mass and weight.

2 What is the standard unit of:
(a) mass
(b) weight?

3 The force of gravity is not the same on all objects. On what property of each object does it depend?

4 What is the weight on Earth of a person with a mass of 50 kilograms?

5 What force keeps the moon in orbit around the Earth?

6 If you were to land on Mars, what would change: your mass, your weight, or both?

7 What two forces act on all falling objects in the Earth's atmosphere?

8 What happens to the air resistance acting on a falling skydiver if he or she speeds up?

9 Explain the meaning of terminal speed.

10 In what way is the moon's orbit around Earth the same as a falling apple?

THINK

11 If every object pulls on other objects with a force of gravity, explain why you don't attract the objects around you.

12 Would you expect your weight to be more on Mars, which has about one-tenth of the mass of the Earth, or the moon, which has about one-hundredth of the mass of the Earth? Explain your answer.

13 On Earth, Belinda has a weight of 450 newtons. What is her mass?

14 If astronauts going to Mars have to take a device to measure out food, would you recommend that they take a beam balance or kitchen scales with a spring inside? Give a reason for your answer.

15 When you drop a nail and a feather from the same height, they reach the ground at different times. Explain, with the aid of a diagram, why this is the case.

16 When riding a roller-coaster on a still day, your hair blows around quite a bit. Why does this happen even though there is no wind?

17 A falling table-tennis ball reaches its terminal speed quite quickly. A falling golf ball takes a long time to reach its terminal speed. Why?

18 Would a table-tennis ball reach a terminal speed on the moon? Explain your answer.

19 What three forces are acting on the bungee jumper on the opening page of this chapter just before reaching the water? Which force (hopefully!) is the largest?

EXPLORE

20 Would a rubber band be as effective as a spring in a force measurer? Design and conduct an experiment to find out. You will need to construct a table and a graph.

INVESTIGATE

21 Find out more about the contributions to science made by Sir Isaac Newton. Write a brief report about his achievements other than his Law of Universal Gravitation.

IMAGINE

22 Imagine that you are working in the first space laboratory on Mars. The pull of gravity is a little more than one-third of what it is on Earth. Write a diary entry for your very first working day in the laboratory. Your diary entry should be an account of your day from 6 am when your alarm rings until 10 pm when you go to bed. Emphasise the effects of less gravity and don't forget that you need to keep physically fit.

eBook*plus*

23 Use the **Bungee game** weblink in your eBookPLUS to simulate a successful bungee jump. Set your mass, rope length and dimensions, and try to achieve the right drop.

work sheets
8.3 Moon Olympics
8.4 Gravity

8.5 SCIENCE AS A HUMAN ENDEAVOUR

Friction — friend or foe?

Friction is the force applied to the surface of an object when it moves against the surface of another object.

Friction can slow down an object, stop it from moving or start it moving. The skater in the photograph below could start moving without friction. He starts rolling by pushing his foot backwards against the path. Imagine what would happen if the path was covered in smooth ice. There would not be enough friction to get him moving forwards. But if the skater is just peacefully rolling forwards, the friction applied to the wheels by the path will slow him down and eventually stop him.

Getting a grip on things

You need friction to do many things. Even walking requires friction. Have you ever slipped on a banana peel?

Even walking requires friction. Without it you have a problem.

When you walk, you push your foot backwards against the ground so that the ground pushes you forward. Without friction your foot would slip backwards as it does on a banana peel. This type of friction, used to assist movement, is called **traction**.

Even holding objects in your hand requires friction. Have you ever dropped wet soap in the shower or bath?

Wet hands and soap provide little grip.

The force of friction is especially important to cars. On a level road, the friction applied by the road when the wheels turn is needed to start a car moving. This friction is another example of traction. Without this friction, the wheels would spin and the car wouldn't start moving. Without friction, cars would not be able to turn corners or stop. The decrease in friction on wet or icy roads makes it very difficult to steer and stop a car.

eBook*plus* **eLesson**

Friction as a driving force
Watch this video lesson to learn about friction and why you couldn't drive a car or even walk without it.

eles-0032

HOW ABOUT THAT!

Crickets use friction to make their familiar chirping sound. The sound is made by friction as they rub the back of the left forewing against a row of teeth on the right forewing.

INQUIRY: INVESTIGATION 8.13

Measuring friction

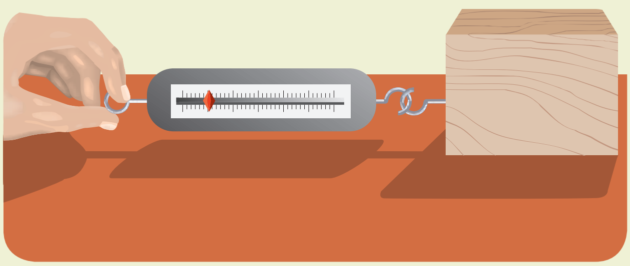
KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

Equipment:

block of wood with hook attached
several identical blocks of wood
spring balance

- Copy the table on the right into your workbook.
- Use a spring balance to pull a block of wood across your desktop. As long as you pull steadily, the reading on the spring balance will be equal to the force of friction on the moving block.
- Record your reading in the table.



A spring balance is used to pull a block of wood across a surface.

- Repeat your measurement two more times on the desktop and calculate the average force of friction. Record all data in the table.
- Repeat this procedure on several other surfaces. Surfaces that you might test are vinyl floor, carpet, doormat, concrete and bitumen.

Friction on different surfaces

	Force of friction (newtons)			
	Trial			
Surface	1	2	3	Average

- Summarise your results in a bar or column graph.
- Design and carry out an experiment to find out the effect of mass on the size of the friction force. Record your results in a table and display them in a line graph.

DISCUSS AND EXPLAIN

1. List the surfaces in order, from greatest friction force to least.
2. What feature of a surface seems to determine the amount of friction?
3. Why was it a good idea to repeat each measurement three times?
4. Do heavier objects experience more friction?

SMOOTH RUNNING

Although friction is necessary for movement and control of movement of people and vehicles on a surface, it can also be a nuisance. Pushing objects across rough surfaces can be very difficult. You have to push it with a force larger than the friction force acting on it. And the heavier the object is, the greater the friction force.

A heavy box on a rough surface is very difficult to move.

Objects can travel faster if they are smooth. Skis and surfboards are waxed and buffed to reduce friction and make them go faster through snow or water.

The smoother the surface on which a vehicle moves, the faster it can go once it gets started. Road surfaces need to be smooth so that vehicles do not waste fuel in overcoming too much friction. However, they need to be rough enough to allow vehicles to turn and brake safely in all types of weather.

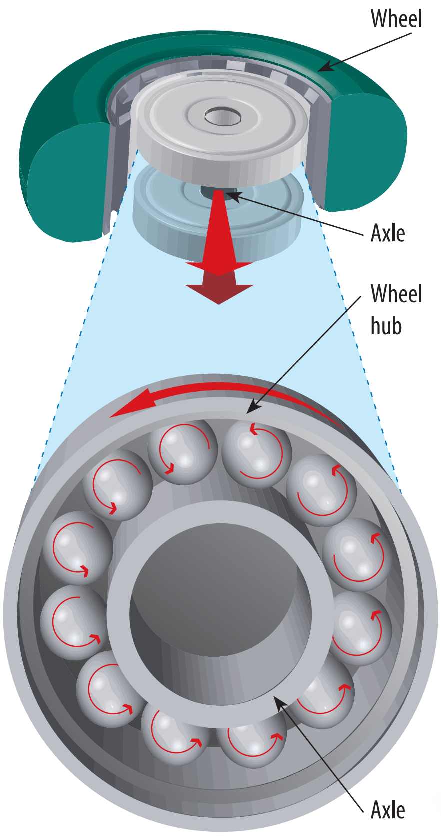
Trains and trams run on steel tracks because they produce very little friction. That makes them cheaper to run than vehicles that move on rough surfaces. Imagine how powerful a bus would need to be to carry the same load as a long freight train!

Olympic bobsled teams spend long hours smoothing and polishing the runners of their sleds.

Even smooth surfaces inside a ball-bearing look rough when viewed under a powerful microscope.

Just rolling around

Ball-bearings are often used to reduce the friction on wheels as they spin around an axle. The ball-bearings act as wheels, allowing the outside ring to 'ride' around the inside ring without sliding. (Rolling friction is much less than sliding friction. Try rolling and sliding an object.) The ball-bearings enable the wheels to turn faster, and reduce wear and tear as they lessen the amount of contact between the surfaces.



Ball-bearings reduce friction between the axle and wheel hub of a skateboard.

What causes friction?

Even very smooth surfaces are rough when you look at them under a very powerful microscope. The photograph at the top of this page shows stainless steel surfaces that look completely smooth. However, when magnified 300 times it can be seen that the surfaces are covered in scratches, making them very rough. It is this roughness that causes friction. The presence of the ball-bearings allows one surface to roll over the other instead of rubbing against each other.

As two surfaces rub together, they get caught on each other. The rougher the surfaces are, the more they get caught on each other, so there is more friction.

Slippery stuff

What makes a door squeak? A squeaky door can be silenced with a few drops of oil. The oil reduces the friction within the hinge. Substances like oil, grease and petroleum are called **lubricants**. They reduce the force of friction produced by the rubbing of solid surfaces. Your joints contain a lubricant called synovial fluid to help stop bones from scraping against each other.

A racing cyclist's helmet, clothing and bicycle are all designed to reduce fluid friction.

WHAT DOES IT MEAN?

The word *lubricant* comes from the Latin word ***lubricus***, meaning 'slippery'.

Lubricants are needed in machines where wear and tear, heat and noise result from surfaces rubbing against each other. Oil and grease are used to lubricate wheel bearings on skateboards, rollerblades and bicycles.

Friction in fluids

Any substance that is able to take up the shape of its container and can flow is called a **fluid**. Air and water are both fluids. Objects travelling through air and water experience fluid friction. Like rolling friction and sliding friction, fluid friction acts against the motion of objects. Fluid friction limits the speed of objects travelling through air and water. It increases the amount of fuel needed by cars, planes, motorised boats and submarines.

Cars, planes, water craft and bicycles are **streamlined** to reduce fluid friction. The faster a vehicle needs to travel, the more important streamlining becomes. Some athletes even shave their bodies to streamline them.

Sports scientists at the Australian Institute of Sport and universities throughout the world are constantly searching for ways to reduce friction so that swimmers, short-distance runners and cyclists can move faster through fluids. Tight-fitting and smooth materials like Lycra® reduce fluid friction through water and air. The design of bicycle helmets is always changing as scientists and engineers find new shapes and materials that reduce fluid friction.

Friction and the space shuttle

One of the most dangerous stages of a space shuttle mission is the re-entry into the Earth's atmosphere. After travelling through space with almost no friction at all, the shuttle fires its engines to slow it down. It enters the atmosphere at a speed of about 26 000 km/h. Because it is travelling so fast, the force of fluid friction is large enough to slow it down to about 2000 km/h within minutes. The temperature on the surface of the wings reaches 1500°C. More than 25 000 special ceramic tiles on the surface of the shuttle prevent it from burning up. They protect the astronauts inside from the incredible heat. As it slows down, the size of the force of fluid friction on the shuttle decreases and it gradually cools down. It zigzags through the lower atmosphere, cooling down and getting into the correct landing path. About one hour after leaving its orbit, the shuttle lands at a speed of about 300 km/h.

Damage to *Columbia*'s ceramic tiles was believed to have caused it to overheat and explode on re-entry in a tragic incident in 2003.

HOW ABOUT THAT!

The dangers of the high friction re-entry of spacecraft into the atmosphere were highlighted in 2003 when the space shuttle *Columbia* broke up 16 minutes before it was due to land. All seven crew members were killed. This tragedy is believed to have been caused by minor damage done to some of the ceramic tiles on the shuttle's surface during launch. This left a very small part of the surface unprotected from the high temperatures caused by friction. The resulting fire quickly reached *Columbia*'s fuel tanks, causing a huge explosion.

INQUIRY: INVESTIGATION 8.14

Investigating the friction of shoes

KEY INQUIRY SKILLS:

- questioning and predicting
- planning and conducting
- processing and analysing data and information
- evaluating
- communicating

Design an experiment to compare the friction of a variety of shoes and a particular floor surface.

- Collect a variety of shoes to test. Include different types of school shoes and runners.
- Identify the equipment you will need to measure the friction that exists between each shoe and a particular floor surface.
- Collect information about each shoe to be tested, such as length, mass, sole material and tread shape.
- Form testable hypotheses about each variable that you decide to investigate.
- Write up the method used in your investigation using a scientific report format.
- Record your results in a suitable table.

DISCUSS AND EXPLAIN

1. Write a suitable conclusion to your experiment.
2. Identify the variables that you controlled and the variables that you would have liked to control but could not.

UNDERSTANDING AND INQUIRING

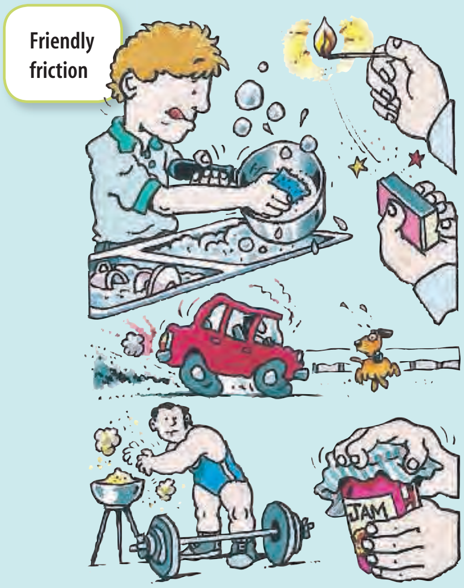
REMEMBER

1. What is the force of friction?
2. Why is friction important when you walk?
3. Friction can cause objects to slow down. What else can it do?
4. How is traction different from other types of friction?
5. List three ways in which friction can be reduced. Give an example of each method.
6. What is fluid friction? List some examples of fluid friction.
7. What is streamlining?

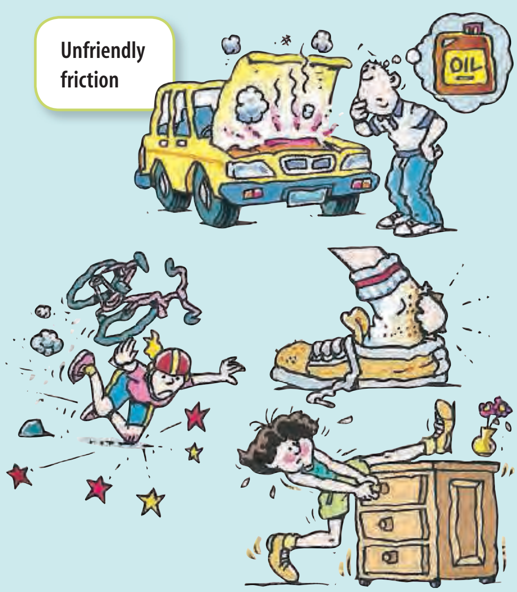
THINK

8 What type of road surface would be safest in wet conditions? Explain your answer.

9 For each of the 'friendly friction' sketches below, state:
   (a) how the friction force is being helpful
   (b) what would happen if the friction force was absent.



10 For each of the 'unfriendly friction' sketches below, state:
   (a) how the friction force is being a nuisance
   (b) what could be done to reduce the effect of the force of friction.



11 Because trains and trams run on steel tracks, the friction force that opposes their motion is quite small. What major disadvantage does this have?

12 Motorists are advised that they will waste fuel if their tyres are under-inflated. Why is this so?

13 How is friction between the moving parts of a car engine reduced?

14 Olympic swimmers wear smooth, tight-fitting suits, streamlining their bodies to reduce friction. Some of them even shave their heads.
   (a) Do you think that shaving heads or legs could give athletes an advantage? Why?
   (b) In which other sports do athletes shave parts of their bodies or wear clothing that reduces fluid friction?

Swimmers streamline their bodies to reduce friction.

IMAGINE

15 Write and present as a play an account of a discussion between seven astronauts aboard the space shuttle as it leaves orbit, re-enters the atmosphere and lands. The re-entry is not as smooth as it should be and the temperature inside becomes dangerously hot. Be creative and dramatic but the play must end with a successful touchdown on Earth.

16 Imagine a world without friction. Form a group of three or four and, together, make a list of things that would be:
   (a) easier to do
   (b) harder to do.

INVESTIGATE

17 Research and report on each of the following questions about car tyres.
   (a) Why do tyres have tread?
   (b) Are wider tyres better than narrow ones? Why?
   (c) How does it affect your driving when the tread is worn away and the tyres are 'bald'?
   (d) How does tread make wet weather driving safer?

18 Using the **Friction as a driving force** interactivity in your eBookPLUS, match different car tyres to the right weather conditions. Run simulations to see if you can achieve the perfect amount of friction. **int-0054**

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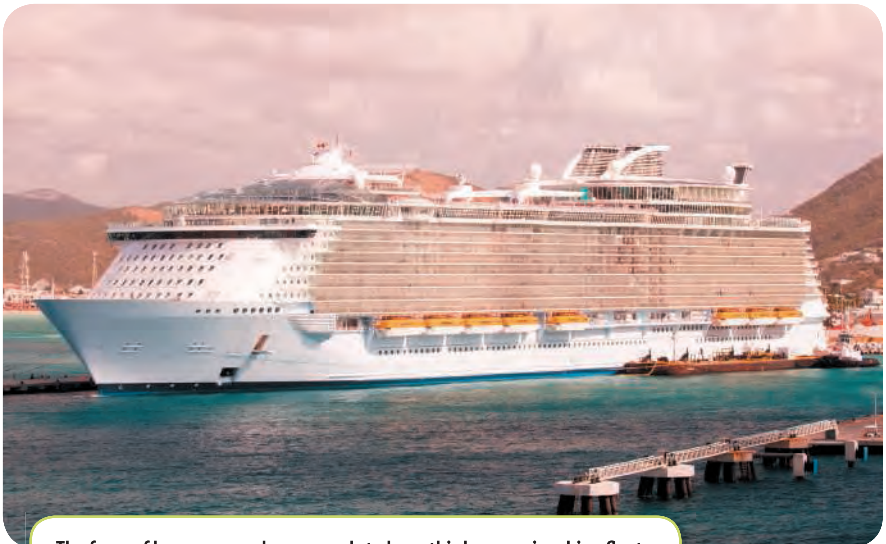
work sheet 8.5 Friction

8.6 SCIENCE UNDERSTANDING

Keeping afloat



The force of buoyancy pushes upwards to keep this huge cruise ship afloat.

The largest cruise ship in the world, *Oasis of the Seas*, has a mass of about 220 million kilograms. The downward pull of gravity on this giant of the sea, its weight, is huge — over 2 billion newtons. Why doesn't it sink?

There must be an upward force equal to its weight. That upward force is provided by the water it is floating on. It's called buoyancy.

Buoyancy is the upward push on an object that is floating on top of or submerged in a fluid. It acts in all liquids and gases. It is the force that keeps helium-filled balloons floating in the air. It is also the force that allows submarines to rise to the surface of the ocean.

Surface tension

In Investigation 8.1, the water appears to be held onto the coin by a skin. There is, in fact, no skin. The water is held in shape by **surface tension**. Surface tension is the pulling of particles in a liquid towards each other. Soaps and detergents reduce the surface tension of water.

If the buoyancy force is greater than the weight of the balloons, they will rise into the air if the girl lets go. If the buoyancy force is greater than the weight of the girl and the balloons, they will take the girl with them.

WALKING ON WATER

The water spider can walk on water. Water spiders are certainly light, but is that the only reason that they do not sink?

Surface tension is what keeps the water spider from sinking and drowning. The small weight of the water spider is well spread out over the surface and is not large enough to push the water particles apart.

The water spider walks on water. Why can't you?

HOW ABOUT THAT!

The buoyancy force of the water in the Dead Sea is so large you can lie back and read a book. The unusual size of the force is caused by the large amount of salt in the water.

INQUIRY: INVESTIGATION 8.15

Are things really lighter in water?

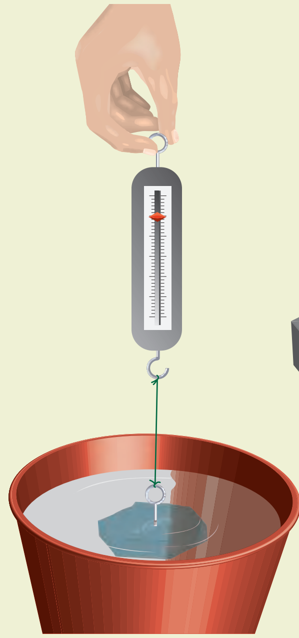
KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

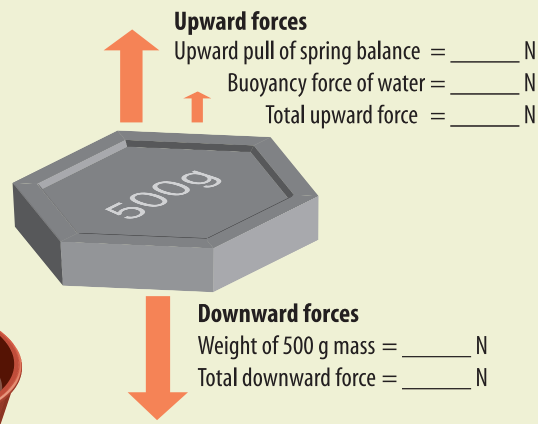
stone
length of string
spring balance
bucket
500-gram mass

- Tie some string around a large stone. Suspend the stone in a bucket of water without letting it touch the bottom.
- Use a spring balance to find the weight, in newtons, of a 500 g mass and record it. Without removing the mass from the spring balance, carefully lower it into the bucket so that it sits just under the surface of the water.
- Record the force measured by the spring balance.



DISCUSS AND EXPLAIN

1 Does the stone feel any lighter when it is in the water? Why?
2 Use the following diagram to work out the size of the buoyancy force on the 500 g mass.
3 Is the 500 g mass really lighter? Explain.



The total force on the mass is zero while it is sitting still under the surface. That means that the total upward force must be equal to the total downward force.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Name two forces acting on you when you float on your back in a swimming pool.
2 What force keeps a water spider on the surface of water?
3 Explain the difference between buoyancy and surface tension.

THINK

4 Which fluid produces the greater buoyancy force — air or water? How do you know?
5 Name the three forces acting on a water spider when it is standing on a still pond.
6 What happens to an object when you plunge it into a fluid and let go:
(a) if the buoyancy force is the same as its weight
(b) if the buoyancy force is less than its weight?
7 Explain in terms of gravity, buoyancy and surface tension why humans can't walk on water.

work sheets
8.6 Buoyancy
8.7 Deep diving danger

INVESTIGATE

8 Different fluids produce different buoyancy forces. Drop a corn kernel or pea into a glass of water and another into a glass of soda water. Which liquid applies the larger buoyancy force? Try to explain why.
9 Design and carry out an experiment to compare the buoyancy and surface tension of water, olive oil and vinegar.
10 Find out what capillary action is and how it works.
11 Cut a slit in the end of a match and gently open it up a little. Float the match in a bowl of water. Carefully place a drop of dishwashing detergent in the split end of the match and watch what happens. Try to explain your observations.

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12 Select liquids and solids in the **Density** interactivity in your eBookPLUS and see what sinks and what floats. **int-0221**

8.7 SCIENCE AS A HUMAN ENDEAVOUR

Staying alive

Every year in Australia, about 1500 people die as a result of road accidents. Many of the deaths and injuries can be avoided.

Safer cycling

Bicycle riders account for well over one-third of road accident injuries in the 10–14-year-old age group. The most serious injuries tend to be to the head and face. The wearing of bicycle helmets has greatly decreased the number of head injuries to cyclists.

A bicycle helmet has a layer of polystyrene foam at least one centimetre thick inside a shell of hard plastic. A cyclist's head falling to the road hits the ground at speeds of up to 20 kilometres per hour. Without a helmet, the head stops suddenly when it hits the ground.

A bicycle helmet is required by law.

The sudden impact can cause serious head injuries. With a helmet, the head stops more slowly as the plastic shell and polystyrene foam are crushed. The injuries are less severe.

Cycling isn't the only sport where you need a helmet. Other activities in which helmets soften the impact of a fall or collision include motorcycling, horse riding and a wide range of sporting activities.

In cars, padded dashboards, collapsible steering wheels and air bags reduce injuries by allowing the upper body to slow down more gradually when a car crashes.

Bend your knees

In some sports, like basketball and volleyball, you need to jump high above the ground. But, of course, what goes up, must come down.

It's best to bend your knees when landing after a high leap.

When you land on the ground, you stop because the surface provides a large upward force. If you land on your feet with your legs straight and rigid, you stop very quickly, even with shoes that cushion. The upward force on your legs is large enough to cause damage. However, if you bend your knees as you land, you stop more slowly and the upward force is less.

INQUIRY: INVESTIGATION 8.16

Egghead

KEY INQUIRY SKILLS:

- planning and conducting
- evaluating

Equipment:

hard-boiled egg
selection of packing materials, such as bubble wrap, foam rubber and newspaper
sticky tape
cardboard
wire

- Design, build and test a container that will hold a hard-boiled egg. Your aim is to create an egg container that will prevent the shell from cracking when it is dropped from a height of 1.5 metres onto a hard floor.

You are actually creating a model of a bicycle accident. The egg represents the head of a cyclist. Your container represents the helmet.

DISCUSS AND EXPLAIN

1 Draw a neat, labelled diagram of your egg container.
2 What features of your container were included to protect the shell from cracking?
3 If your 'egg head' was 'injured', suggest how you could improve the effectiveness of your container.

Belt up

When a car collides head on with an obstacle or another vehicle, the occupants continue to move forwards after the car stops. In fact, they continue to move forwards with the same speed and direction that the car had before the collision until they are stopped by a force. Without seatbelts the occupants would fly forwards through the windscreen, or their bodies would be stopped suddenly by the steering wheel, dashboard, roof or other parts of the inside of the car. Most deaths and injuries in car accidents are caused by a collision between the occupants and the inside of the car. With properly fitted seatbelts, car occupants stop as the car stops and are less likely to be killed or injured.

Your body is not the only thing that will keep moving once the car stops as a result of a collision. Any loose objects in the car will continue to move after the car stops. You should therefore never leave any loose objects in the car. They are much safer in the boot! In one accident a driver was killed by a paperback novel that was sitting on the shelf behind the back seat. It continued to move after the car and driver (with properly fitted seatbelt) stopped. A corner of the book struck the driver in the back of the head, killing her instantly. Unrestrained pets are also dangerous in a collision.

INQUIRY: INVESTIGATION 8.17

Crash test dummy

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

Equipment:

pencil sharpener or eraser
toy car
rubber band
block of wood
clamp

- Clamp a wooden block to the end of a table.
- Place the pencil sharpener or eraser on the toy car to represent an occupant. Push the toy car towards the wooden block as fast as you can without your 'crash test dummy' falling off. Observe the motion of the crash test dummy after the car collides with the wooden block.
- Modify this experiment to include 'seatbelts' (by using a rubber band).

DISCUSS AND EXPLAIN

1 Describe the motion of both the car and the crash test dummy after the collision without the 'seatbelt.'
2 What difference does the rubber band make to the motion of the crash test dummy during and after the collision?

UNDERSTANDING AND INQUIRING

REMEMBER

1 How do bicycle helmets protect the head in an accident?
2 Describe the likely motion of an unrestrained rear seat passenger in a car that collides with a tree at 60 kilometres per hour.
3 Explain how seatbelts decrease the chance of injury or death during a road accident.

THINK

4 Bicycle helmets were made compulsory in Victoria on 1 July 1990. Why do you think it was necessary to make a law to force people to wear them?
5 When a stationary car is hit from the rear by another vehicle, it is pushed forwards rapidly. Describe the likely motion of a front seat passenger:
   (a) with a head rest fitted to the seat
   (b) without a head rest fitted to the seat.
6 List as many sports as you can in which helmets are worn to protect participants from head injuries.

CREATE

7 Design a poster with the title 'Don't be an egghead. Wear a helmet'.

INVESTIGATE

8 Find out the meaning of the word 'inertia'.
9 Use the internet to research and report on the following questions.
   (a) What evidence is there that the compulsory wearing of bicycle helmets in Australia has saved lives and prevented critical brain injuries?
   (b) Not everybody believes that the wearing of bicycle helmets should be compulsory. Use a two-column table to list the reasons for and against the compulsory wearing of helmets.
10 Find out who Sir Isaac Newton was. What is Newton's First Law of Motion and how is it relevant to seatbelts in cars?

Cluster maps and single bubble maps

how to ...?

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.

question

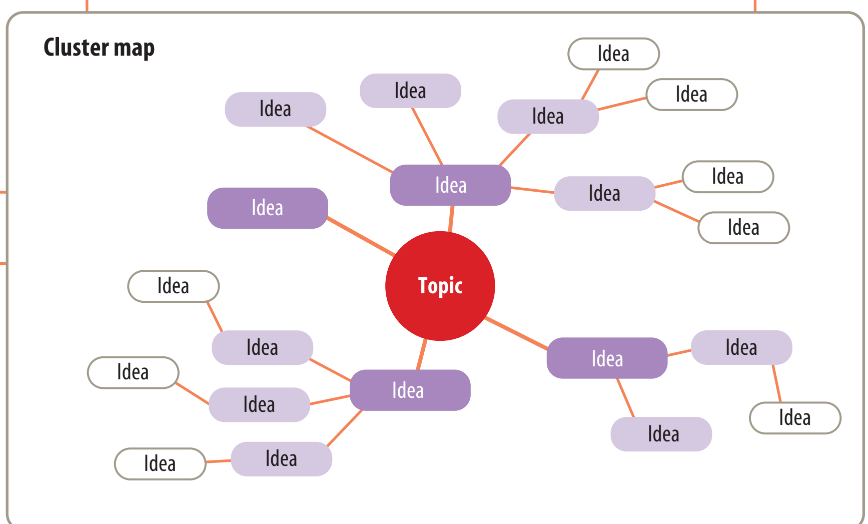
How can I develop a particular idea?

why use?

To stimulate the generation of new ideas

also called

Mumbles; brainstorm map; spider diagram



comparison

Similarity

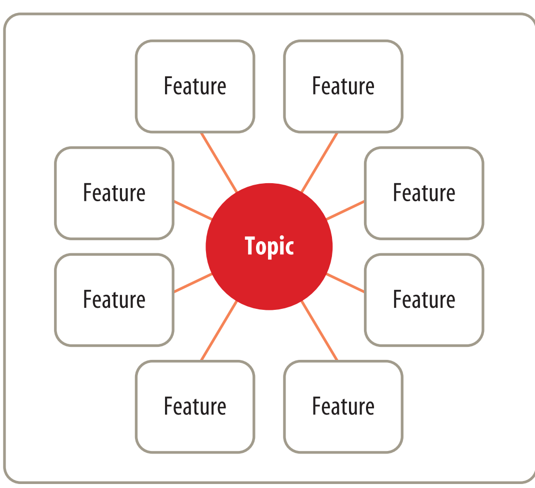
Both have links around a central topic.

Difference

Single bubble maps have only one level from the centre while cluster maps can have numerous levels.

Single bubble map

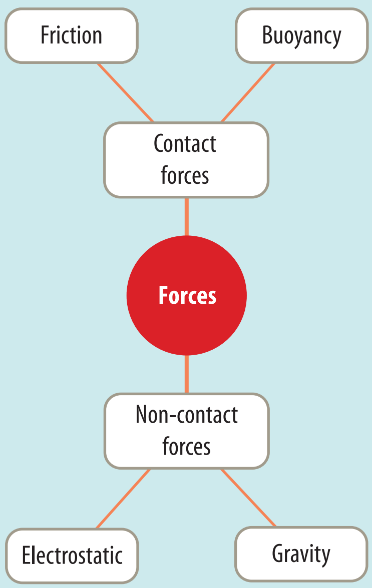
example



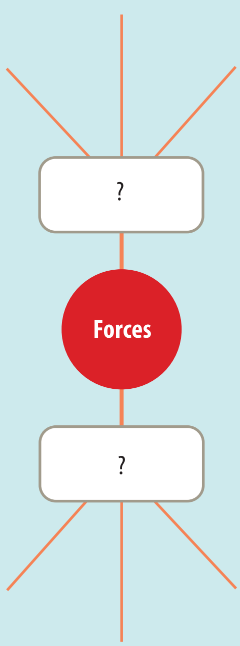
UNDERSTANDING AND INQUIRING

THINK AND CREATE

1 (a) Copy and complete the cluster map below to show the links between the types of forces described in this chapter. Add as many links as you can to the map. Don't forget that you can sometimes make links between the different 'arms' of your cluster map.

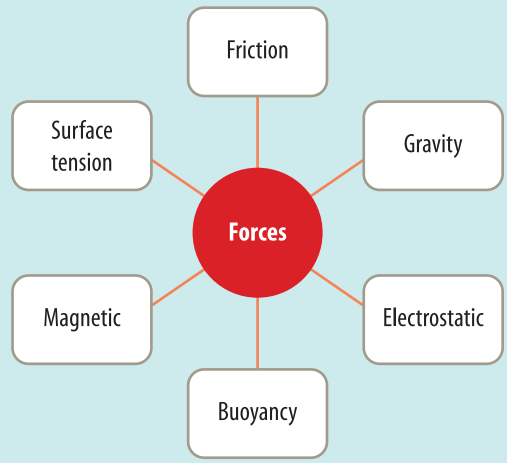


(b) Suggest a different way of dividing the six forces into two groups and draw a new cluster map starting with these two groups branching from the title. Use the cluster map below as a starting point.



2 A single bubble map like the one below can be used to make it easier to draw a cluster map. This simple bubble map shows the six types of forces.

When they are displayed in a bubble map, the links between them are sometimes easier to see. In this case, the bubble map can help you see that the six forces fall into two groups — contact forces and non-contact forces.



3 Create a single bubble map for each of the following forces.
(a) Gravity
(b) Magnetism
(c) Friction

Before you create each map, brainstorm in a small group to make a list of words associated with the force. For example, your 'gravity' list might include words such as fall, weight, pull, down and non-contact.

4 (a) Draw a single bubble map with the title 'What forces can do'.
(b) In pairs, compare your bubble maps and draw a new one that combines your ideas.
(c) Form teams of 4 or 6. Again, compare your bubble maps and draw a single bubble map for the team on a large sheet of paper. Use the detail of the team's single bubble map to construct a cluster map for your team on a large sheet of paper.

STUDY CHECKLIST

FORCES AND THEIR EFFECTS

- identify and describe the changes in motion caused by forces
- distinguish between contact and non-contact forces
- represent the forces acting on an object in a diagram
- recognise situations in which the forces acting on an object balance each other out

MAGNETISM

- distinguish between magnetic and non-magnetic substances
- describe the forces between magnets and between magnets and other objects
- represent the magnetic field in the region of magnets and around the Earth
- use a compass to determine the direction of a magnetic field
- explain how an electromagnet works
- identify some of the uses of electromagnets

ELECTRIC FORCES

- explain how objects become charged
- describe the forces between charged objects and between charged and uncharged objects
- relate natural events such as lightning and electrostatic shocks to the build up of electric charge
- outline some uses of static electricity

GRAVITY

- distinguish between weight and mass
- investigate falling objects and relate their motion to gravity and air resistance

CONTACT FORCES

- describe friction as a force that opposes motion
- identify situations in which friction is useful and others in which friction is a nuisance
- distinguish between buoyancy and surface tension

SCIENCE AS A HUMAN ENDEAVOUR

- describe some of the work done by sports scientists to improve the performance of athletes, swimmers and cyclists by reducing friction
- explain how the effects of friction make the re-entry of spacecraft into the Earth's atmosphere dangerous and how these effects are controlled
- relate the importance of wearing bicycle helmets and seatbelts to the effect of forces on motion

INDIVIDUAL PATHWAYS

eBook plus

Activity 8.1
Investigating forces
doc-6063

Activity 8.2
Analysing forces
doc-6064

Activity 8.3
Investigating forces further
doc-6065

ICT

eBook plus Summary

eLESSONS

Producing static electricity

Learn about static electricity, how it is created and the effect that charged and uncharged objects have on each other when they are put together. Watch static electricity produced by charging perspex and ebonite rods. A worksheet is attached to further your understanding.

Searchlight ID: eles-0067

Friction as a driving force

In this video lesson, you will learn about friction and discover its importance in everyday life. You will see practical examples of friction and learn why you couldn't drive a car or even walk without it.

Searchlight ID: eles-0032

INTERACTIVITIES

Friction as a driving force

This interactivity helps you to apply your knowledge of friction to driving. Match the right tyres to the weather conditions, and see if you can achieve the perfect amount of friction.

Searchlight ID: int-0054

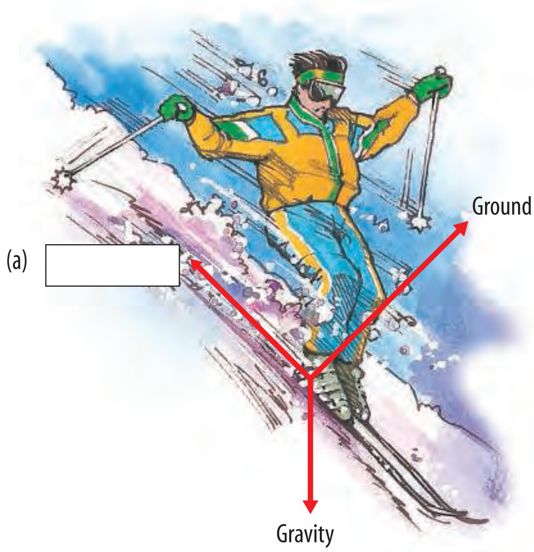
Density

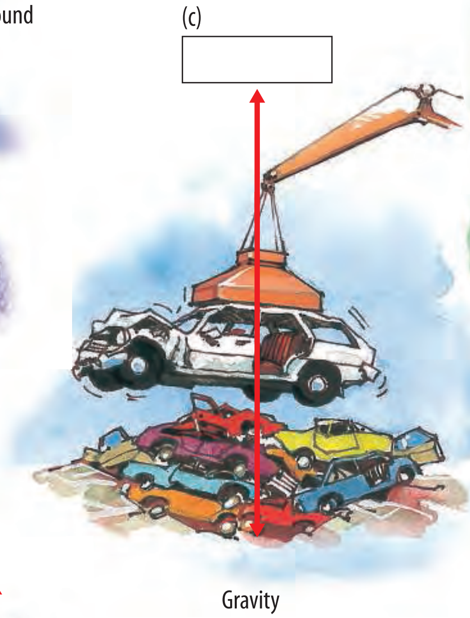
This interactivity helps you to delve into the world of density. Select a liquid to fill your virtual flotation tank, and then choose a solid to release into it. Discover the combinations that cause your solid to sink and to float.

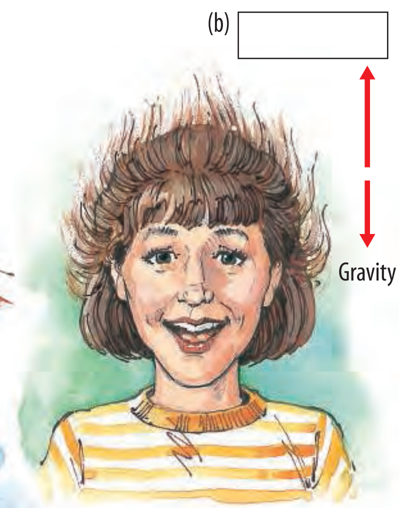
Searchlight ID: int-0221

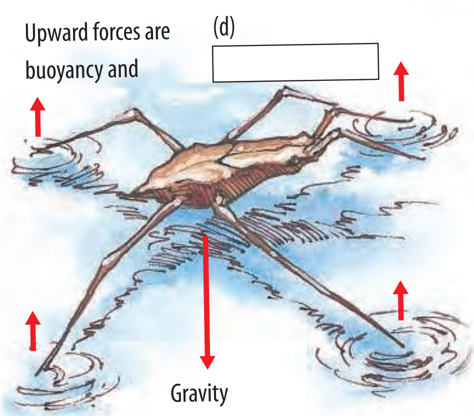
LOOKING BACK

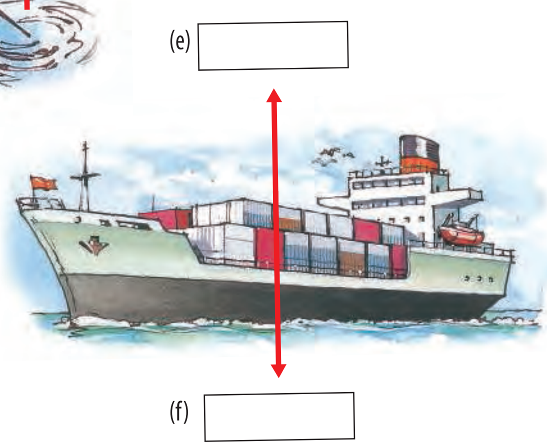
1 Copy and complete the diagrams below, filling in the missing force labels.



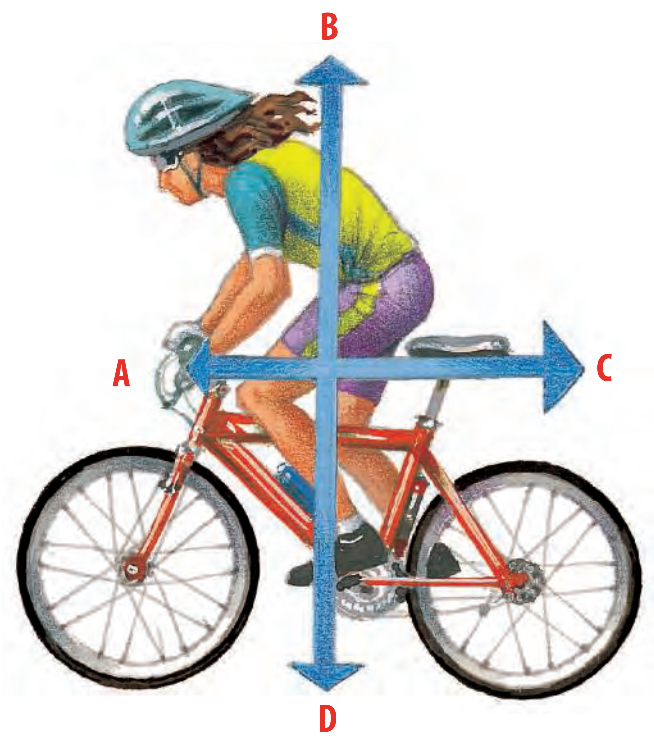








2 The arrows in the diagram below represent four of the forces acting on a cyclist riding on a smooth, flat surface.



(a) Which two forces are equal in size?

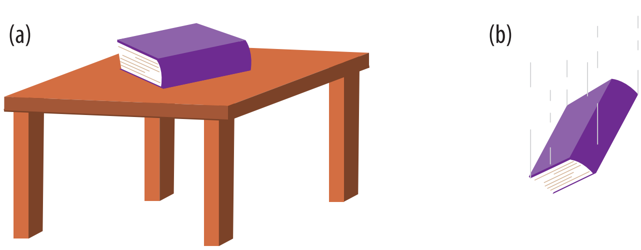
(b) Which arrow could represent air resistance?

(c) Is the cyclist speeding up, slowing down or travelling at a steady speed? Explain your answer.

3 Redraw the diagrams below using arrows to represent the forces acting on the book:

(a) while it is at rest on the desk

(b) while it is falling towards the floor.



4 The compass needle is not shown in the diagram below. Redraw the diagram to show the direction in which the needle would point.

5 Explain why a compass always points towards the North Pole of the Earth when it is away from other magnets.

6 Electricians use screwdrivers and long-nosed pliers with handles that are coated with plastic. Suggest a reason for this.

7 When you rub your shoes on some types of carpet, your body becomes negatively charged. Explain what will happen to the extra negative charge on your body if you:

(a) stand still for a few minutes

(b) touch a metal door handle immediately after rubbing your shoes on the carpet

(c) place the palm of your hand near a negatively charged balloon hanging from a thread

(d) place the palm of your hand near a positively charged balloon hanging from a thread.

8 Use a series of labelled diagrams to explain how a positively charged balloon can be attracted to an uncharged plaster wall.

9 Explain why the pull of gravity is less on the moon than it is on Earth.

10 State the units used to measure:

(a) mass

(b) weight

(c) force.

11 When a package of emergency supplies is first dropped from a plane, it gains speed rapidly. Explain why it eventually stops gaining speed before reaching the ground, even without the use of a parachute.

12 Describe at least three ways in which racing cyclists reduce the effect of air resistance on their motion.

13 Identify the force that:

(a) pushes you up when you are swimming underwater

(b) causes all objects with mass to attract each other

(c) acts on an object when it moves across the surface of another object

(d) resists the motion of all objects moving through the air

(e) pushes up on objects on the surface of water, but not on objects below the surface

(f) can lift a paperclip from a desktop.

14 Describe how your body would move if you were a passenger in a car that stopped very suddenly and you were not wearing a properly fitted seatbelt.

15 Explain how the thick layer of polystyrene foam or similar material inside the outer shell of a helmet reduces the likelihood of severe head injuries in an accident.

work sheets
8.8 Summing up
8.9 Crossword