4 Forces

Planning page

Getting started

4.1 Forces around you page 69
- Activity page 69
- Investigate 11 Everyday forces
- Investigate 12 Demonstrating forces
- Activity page 74
- Animation Motorcycle forces

4.2 Friction page 77
- Investigate 13 Measuring friction
- Assessment task 4 Friction

4.3 The pull of gravity page 83
- Activity page 84
- Skillbuilder page 85 Drawing lines of best fit
- Experiment Stretching a spring
- ICT skillsheet Getting started with Microsoft Word

Main ideas
- Chapter 4 crossword

Review
- Chapter 4 test

Essential Learnings for Chapter 4

Essential Learnings	*References*		
	Student book (page number)	***Workbook (page number)***	***Teacher Edition CD (Assessment task)***
Knowledge and understanding *Energy and change* An unbalanced force acting on a body results in a change in motion	pages 69–87	pages 30–34	Assessment task 4 Friction
Objects remain stationary or in constant motion under the influence of balanced forces	pages 69–87	pages 30–34	Assessment task 4 Friction
Science as a human endeavour People from different cultures contribute to and shape the development of science	page 86		
Ways of working Plan investigations guided by scientific concepts and design and carry out fair tests	Investigate 12 page 72 Investigate 13 pages 77–78 Experiment page 85	pages 30–31	Assessment task 4 Friction
Evaluate data, information and evidence to identify connections, construct arguments and link results to theory	page 83 Experiment page 85		
Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question	Investigate 13 pages 77–78 Experiment page 85		
Select and use scientific equipment and technologies to enhance the reliability and accuracy of data collected in investigations	Experiment page 85		

QSA *Science Essential Learnings by the end of Year 9*

Vocabulary

attraction
buoyancy
contact
electrostatic
friction
gravitational
gravity
lubricant
magnetic
mass
newton
resistance
weight

Focus for learning

Solve problems whose solutions involve the application of forces (page 68).

Equipment (per group)

Investigate 11 pages 70–71	**Part A:** table tennis ball, drinking straws
	Part B: 20 cent coin, scissors and paper
	Part C: piece of paper, plastic pen or ruler
	Part D: 2 bar magnets
	Part E: bucket of water, different types of balls (golf, table tennis, rubber, styrofoam)
Investigate 12 page 72	Students design their own investigation. They will need a rubber band, tennis ball, playdough, a bar magnet and some paperclips.
Investigate 13 page 77	large hardwood block with a hook (or bent nail), 5 N spring balance, piece of sandpaper
Experiment page 85	Students will need a spring and some masses.

4 Forces

Getting Started

Work in a small group to solve one or more of the following problems:

- Suppose a large asteroid has been detected on a collision course with Earth. What could be done to prevent the collision?
- You want to find out which type of adhesive tape is best for sticking things to the bench. Design an experiment to find out.
- You want to design and build a billycart that will beat all others in a 100 m downhill race. Discuss the features you would include in your design.

Starting point

This chapter requires students to visualise concepts or think in the abstract, and some students will find this difficult. Many students need to 'see it to believe it', so try to use real-life examples in the learning experiences where possible. This will help students to assimilate new and difficult concepts. Drawing on a variety of learning styles while teaching this chapter will not only reinforce ideas but will also make the learning process more relevant and enjoyable. There are ideas for catering to different learning styles in this Teacher Edition.

Allow the students to investigate the effect of magnets when two are brought together. Try using different-shaped ones such as horseshoe or circular magnets.

Get the students to rub their jumper or hair with a plastic pen. Bring the pen towards another student's hair, making sure it does not touch. What happens?

The students could drop various items from different heights. Why does each object fall to the ground regardless of what it is or the position from which it was dropped?

You could have a game of tug-o-war outside to introduce the idea of forces being pushes and pulls.

4.1 Forces around you

When you lie in bed at night everything is so still it seems that nothing moves. But your chest moves up and down as you breathe, and your heart is pumping blood throughout your body. While this is happening the Earth is hurtling through space at 100 000 kilometres per hour! All this motion is caused by forces, which affect you every moment of your life.

Forces are pushes or pulls. They can start objects moving, and they can stop, speed up, slow down, or change the direction of moving objects. They can lift things, or cause them to turn, bend or twist. They can also prevent motion; for example, a handbrake on a car stops it from rolling down a hill.

Activity

Look at the cartoon below. Find examples of:

a pushing forces (what is doing the pushing?)

b pulling forces (what is doing the pulling?).

Which of the examples are:

- forces caused by gravity
- lifting forces
- forces where something bends
- muscular forces
- electrical forces
- magnetic forces?

Hints and tips

You may not be able to *see* a force, but you can experience a force's effect. One way for the students to experience a force is by using magnets. They can feel the *pull* of attraction and the *push* of repulsion.

Learning experience

Write the word *forces* on the board and ask students, one at a time, to come up and contribute to a concept map. Lead the discussion so that you cover the forces that will be investigated in this chapter.

Ask students to list forces that they might experience in everyday life. Alternatively, show the class pictures from magazines or books which illustrate everyday experiences, and ask students to describe the possible forces that are acting on the objects in the pictures.

Learning experience

Students could draw their own cartoon illustrating forces. On their picture they should draw arrows indicating whether each force is a push or a pull. The more-able students could label the type of force illustrated. You might like to write a list of words on the board for them to use in their descriptions.

Lab notes

Part A

Ask students to predict what would happen in Part A if a shorter or wider straw was used. Test their predictions.

Part B

An alternative or addition to Part B is to drop two objects of different masses from the second level of a building. Ask students to predict what will happen.

Investigate

11 EVERYDAY FORCES

Aim

To experience a range of different forces.

Planning and Safety Check

This experiment has five parts. Discuss with your teacher whether you will do all parts or whether different groups will do different parts. Make sure you read the instructions before you start.

PART A
Pushing forces

Materials

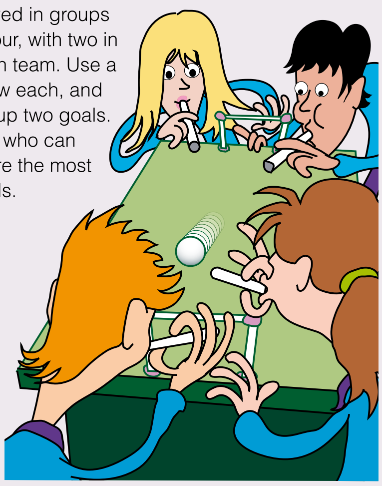
- table tennis ball
- drinking straws

Method

1 Use the table tennis ball and a straw to answer these questions.
   - **a** What happens if you blow on the ball while it is moving towards you?
   - **b** What happens if you blow on it while it is moving away from you?
   - **c** What happens if you blow on it while it is moving across in front of you?

   Discuss your answers with others.

2 Play a game of blowball. This game is played in groups of four, with two in each team. Use a straw each, and set up two goals. See who can score the most goals.



PART B
Gravitational force

Materials

- 20 cent coin
- scissors and paper

Method

1 Cut out a piece of paper the size of the coin.

2 Hold the piece of paper in one hand and the coin in the other, at the same height. Drop them both at the same time.
   Write an inference to explain what happened. Say what forces were acting on the coin and the paper, and in which direction they were acting.

3 Roll the paper into a ball and drop it and the coin again.
   Write an inference to explain what happened.

PART C
Electrostatic forces

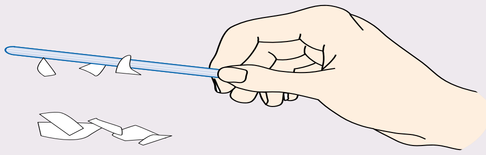
Materials

- piece of paper
- plastic pen or ruler

Method

Tear a piece of paper into small bits. Rub a plastic pen briskly on your clothes. (A woollen jumper works well.) What happens when you bring the pen near the pieces of paper?

The force acting here is due to an electro-static charge on the pen. Does the pen need to be touching the paper, or can the electrostatic force act over a distance?



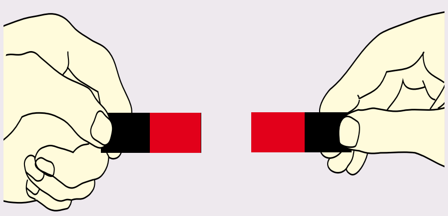
PART D
Magnetic forces

Materials

- 2 bar magnets with their poles marked

Method

1. Hold one magnet in each hand. Feel what happens as you slowly bring the end of one magnet close to the end of the other.
2. Repeat the test, but use the other end of one of the magnets.



Write a generalisation describing the forces acting between the two magnets.

PART E
Buoyancy forces

Materials

- bucket of water
- balls of different types, eg golf, table tennis, rubber, styrofoam

Method

1. Put a table tennis ball into a bucket of water. Push it to the bottom of the bucket and let it go.

2. Do the same with the other balls.

What forces act on a ball in water? In which direction do they act?

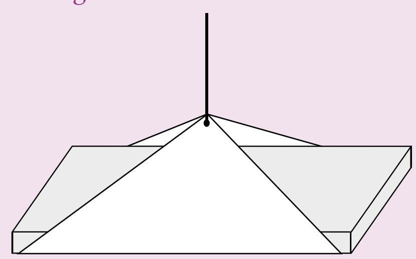
Try to write a generalisation about what happens to different balls in water.

Learning experience: magnetic fields

Place a piece of paper on top of a bar magnet. Gently sprinkle some iron filings on the paper. Magnetic field lines will appear on the paper.

You could also experiment with two magnets, placing them north to south. Keep them a few centimetres apart so that the attractive forces do not push the magnets together. Place the paper on top and sprinkle the iron filings over the paper.

Make a paper cradle for a bar magnet as shown in the diagram below and suspend it from the clamp on a retort stand so that the magnet can move freely. See which end of the magnet faces the north.



Research

- Students could investigate the difference between the South Pole and the Magnetic South Pole.
- Ask students to research what lightning strikes are and how they occur.

Learning experience: bend water

Rub a plastic (Perspex) rod or pen with a woollen cloth. Turn the tap on so that a slow but steady stream of water flows. Gently bring the rod or pen close to the water and watch it bend. See page 231.

Learning experience: hair raising

Use a Van der Graaff generator to show electrostatic forces. The machine will work best on a dry day. Too much humidity will produce poor results. Ensure that the generator has been switched off and earthed before students place their hands on the dome. To earth, simply touch the dome with the hand rod. Sometimes a spark can be seen. See page 230.

Hints and tips

As part of the students' note-taking, they could construct a chart with two columns using the headings 'What do forces do?' and 'An example'. For each dot point in the text they should be able to write an example.

What do forces do to objects?

You have seen so far that forces can:

- start motion
- stop motion
- speed up motion
- slow down motion
- change the direction of motion
- change the shape of an object.

Some of these forces act by contact and are called *contact forces*. For example, when you push something by hand, or pull it with a rope, you are using contact forces. Other examples are the wind blowing the trees and ocean waves crashing on rocks.

Some forces do not need contact, and can act at a distance. These are *non-contact* forces. For example, two magnets exert a force on each other without even touching. Other examples of non-contact forces are gravitational and electrostatic forces.

Lab notes

Make sure students read this investigation prior to the lesson. If time permits, allow the groups to discuss their plan for 10–15 minutes in the lesson before, so that a draft plan can be drawn up, perhaps for homework.

This investigation doesn't require a formal report write-up. Instead, a large table with the suggested headings in each of the four columns and the student responses below them is sufficient. Ensure that the plan is checked, either by their peers or by you, before each group starts their investigation.

Investigate 12 DEMONSTRATING FORCES

Aim

This is a 'design-it-yourself' investigation.

You have to design ways to show the six things that forces do to objects (see the list at the top of the page). Say which of the forces are contact forces and which are non-contact forces.

Materials

You will be given a rubber band, a tennis ball, a piece of playdough, a magnet and some paperclips. You can use other materials, but you will have to discuss the use of these with your teacher.

Planning

1 In a small group, discuss how you will show each of the six things forces do to objects. For example, for 'starting motion' you might flick a tennis ball with a ruler.

2 Think of ways to demonstrate both contact forces and non-contact forces.

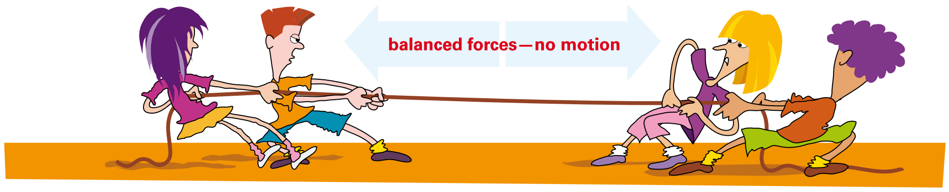
3 Show your plan to your teacher before you start.

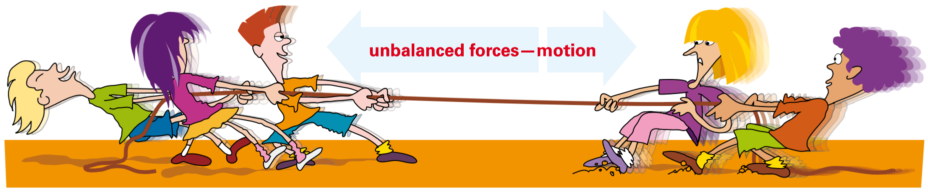
Writing your report

Draw up a large table with *What we did, What we observed, What the force did* and *Contact or non-contact force* as column headings.

Balanced and unbalanced forces

In a tug-of-war there are two equal forces acting in opposite directions. There is no motion until one force becomes greater than the other. You can use arrows to show the direction and strength of the forces.



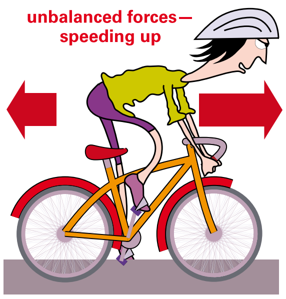


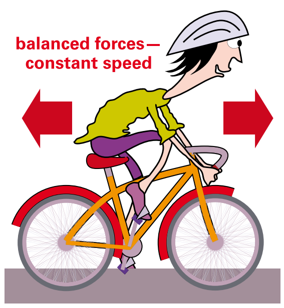
Bicycle forces

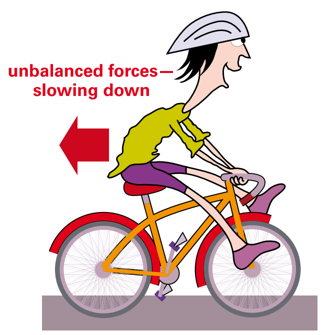
To start off riding your bike, you use your muscles to push on the pedals. This force then turns the back wheel, which pushes on the road causing the bike to start moving. There are also frictional forces that tend to slow you down.

However, your pushing force is greater than the frictional forces and the bike speeds up. The forces are *unbalanced*, causing an increase in speed.

When you reach a constant speed the forces are *balanced*. If you stop pushing on the pedals, the forces are again unbalanced, and the bike soon stops (unless you are going down a hill!).







Working with technology

To see what forces act on a motorbike, open the **Motorcycle forces** animation on the CD.

Hints and tips

When an object is moving at a constant speed the net force is zero. When the net force is zero it means that all forces acting on the object are balanced. If there is a net force of zero acting on an object it does not mean no forces are acting on it. A cyclist riding at a constant speed is still applying a pushing force to the pedals. To start something moving requires a force, likewise to stop its motion. This is Newton's first law of motion (inertia).

Ask the students to think about what factors may affect the size of a force.

Animation

Students should view the animation **Motor cycle forces** on the CD.

Learning experience

After students have studied page 73 and done Check! 2 on page 75, ask them to draw a simple diagram of each of the following objects:

- a rocket being launched
- a car accelerating from traffic lights
- a ball falling
- books on a desk.

Ask students to label all the forces acting on each of the objects. They should include arrows indicating the strength and direction of each force. For example, if the force is large, draw a long, thick arrow. If the force is small, make the arrow short and thin.

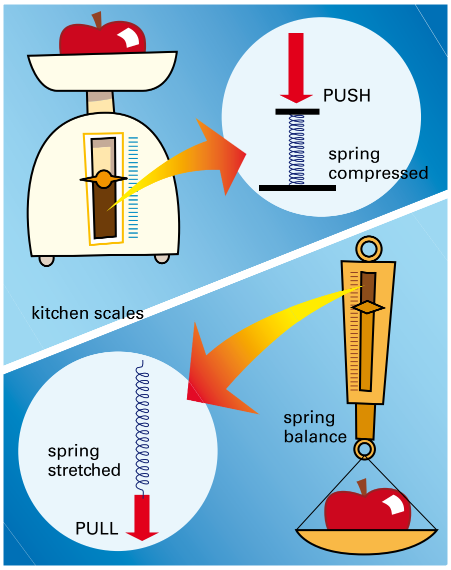
This will help to establish types of forces and create a pictorial representation of whether the forces are balanced or unbalanced.

Hints and tips

It may be appropriate to introduce and discuss the difference between weight and mass. However, it is dealt with on page 83. Newton meters (spring balances) generally show both the weight and mass.

Measuring forces

A spring stretches when a pulling force acts on it, and is squashed or compressed when a pushing force acts on it. The bigger the force, the more it is stretched or compressed. For this reason, a spring can be used to measure the strength of forces. A pointer attached to the spring moves as the spring changes its length, and the force can be read on a scale. To measure larger forces you use a stronger spring. Spring balances measure pulls, and kitchen or bathroom scales measure pushes.



The unit used to measure force is the **newton** (N), named after Sir Isaac Newton. The table below gives you some idea of the approximate sizes of some forces.

force to lift an apple	1 N
force to lift a 1 kg bag of sugar	10 N
force you exert by sitting on a chair	500 N
force needed to launch space shuttle	33 000 000 N

You can also use force measurers in a horizontal position. For example, you can use a spring balance to measure the force needed to pull a door open.

Activity

Obtain several different spring balances, eg 5 N, 20 N and 100 N. If possible, obtain some kitchen scales, eg 2 kg (20 N) and some bathroom scales, eg 120 kg (1200 N).

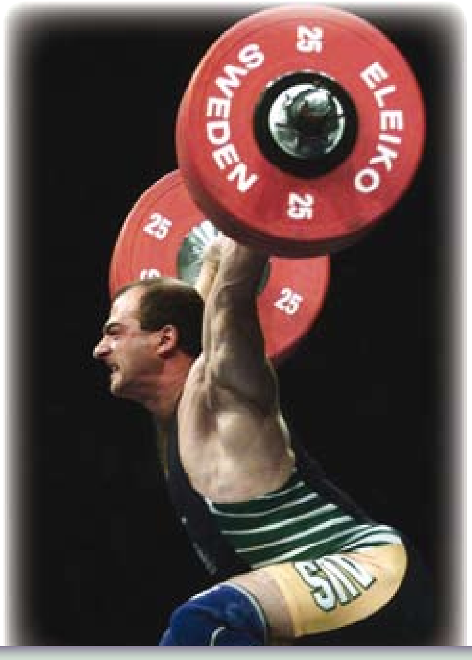
If the scale is in kilograms, multiply by 10 to get newtons. If the scale is in grams, divide by 100 to get newtons.

Measure a range of pulls and pushes. For pulls use a spring balance. For small pushes use kitchen scales, and for large pushes use bathroom scales.

You could measure the force needed to:

- push or pull a sliding door
- open a can of soft drink
- pull sticky tape off the bench
- break a piece of fishing line
- turn on a light switch
- lift a shot-put
- push a button on an electrical appliance.

Record all your measurements in a data table.



Learning experience

In groups, ask students how else they can measure forces being applied to different objects. Each group should design an experiment to measure the forces acting on objects. The measurements need not be quantitative.

Check!

1 Copy and complete the sentences below. Choose from these words:

direction pull move push change

- **a** A force is a ______ or a ______ .
- **b** When you open a door, you ______ .
- **c** When you lift something, you ______ .
- **d** A force can also ______ the shape of an object.
- **e** A force can make things ______ .
- **f** A force can also make moving things change ______ .

2 The diagrams show some forces in action. The forces are shown with arrows.

- **a** For each picture name the object that the force acts on. For example, in **A** the force acts on the ball.
- **b** Choose from the list below to say what the force is doing in each picture.
  - starting an object moving
  - slowing down an object that is moving
  - changing the direction of movement
  - balancing another force, and preventing movement
  - bending an object

3 Some forces can act over a distance, rather than by contact.

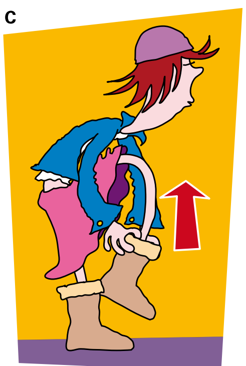
- **a** What does this statement mean?
- **b** Name three types of forces that can do this.

4 What forces cause a bike to slow down when you stop pedalling?

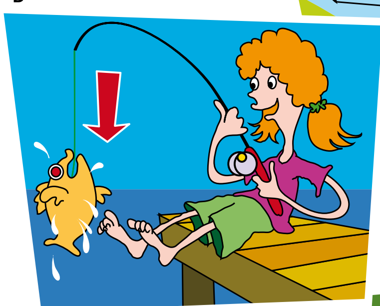
A

B

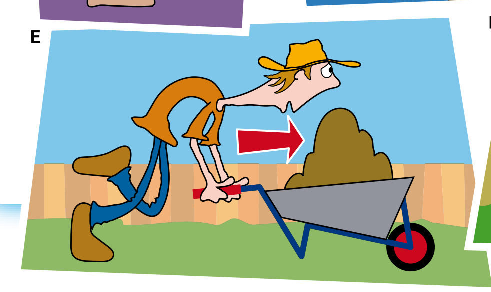
C



D



E



F

Check! solutions

1
- a A force is a **push** or a **pull**.
- b When you open a door, you **push OR pull**.
- c When you lift something you **pull**.
- d A force can also **change** the shape of an object.
- e A force can make things **move**.
- f A force can also make moving things change **direction**.

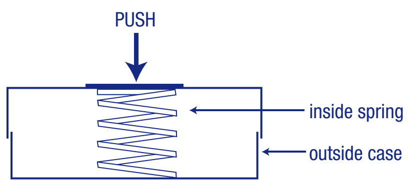
2
- a In **A** the force acts on the ball.
  In **B** the force acts on the billy cart.
  In **C** the force acts on the boot.
  In **D** the force acts on the end of the rod.
  In **E** the force acts on the wheelbarrow.
  In **F** the force acts on the dog's collar.
- b In **A** the force is changing the direction of movement.
  In **B** the force is slowing down an object that is moving.
  In **C** the force is starting an object moving.
  In **D** the force is bending an object.
  In **E** the force is starting an object moving.
  In **F** the force is slowing down an object that is moving.

3
- a The statement means that sometimes it looks like magic because there is nothing touching the objects.
- b The best examples are gravity, electricity and magnets.

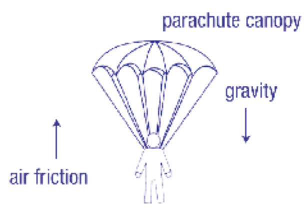
4 The forces which will slow down a bike include friction between the tyres and the road, friction between the wheels and the axle and friction with the air.

5 The answers are:
a 9 kg, 46 newtons (N) and 140 grams
b 90 N and 1.4 N
c The bathroom scales show the greatest force and the force is a push.

6 Most bathroom scales have a big spring in the middle which slowly compresses as it is pushed down as shown in the diagram.



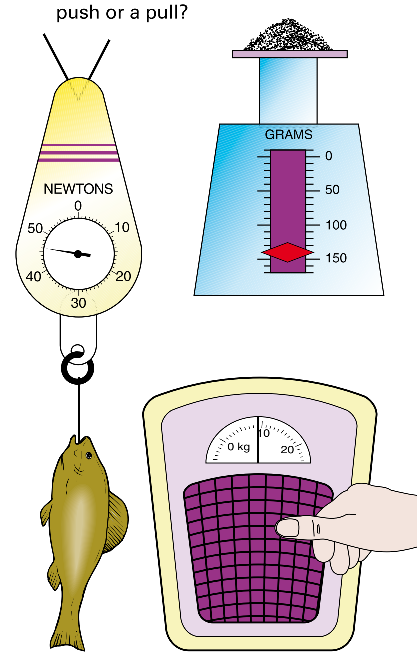
7 If the two forces are exactly equal then the person will be falling at a steady speed.



8 a The balanced forces are the force of gravity on your body acting downward and the force upward exerted by the chair.
b If the force of gravity is stronger than the legs then the legs will bend or break and you will fall to the floor.

9 As you are abseiling down the cliff the force of gravity is pulling you downward and the forces of friction with your hands on the rope and feet on the rocks are working in the opposite direction.

5 Look at the spring balance, kitchen scales and bathroom scales below.
a Write down the reading on each.
b Where necessary convert the reading to newtons.
c Which shows the largest force? Is it a push or a pull?



6 How do the bathroom scales in Check 5 work? Draw a diagram.

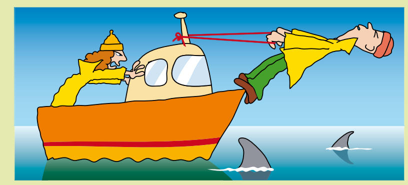
7 Sketch a person parachuting from a plane. Draw arrows to represent the forces acting on the person. When are the forces balanced?

8 You are sitting on a chair. There are two balanced forces.
a What are the forces?
b What would happen if these forces were not balanced?

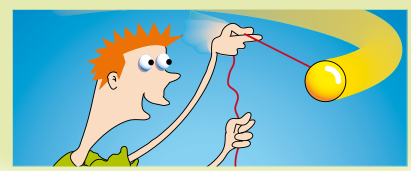
9 Imagine you are abseiling down a cliff. What are the two forces acting on you? Are they balanced?

challenge

1 Forces are measured in newtons. How would you explain to someone how big a force of 20 newtons is?
2 'A car travelling in a straight line at constant speed has no forces acting on it.' Explain why this statement is false.
3 A cricketer hits a ball into the air. Is there a force on the ball while it is in the air? Explain.
4 In which direction will this boat move? Explain your answer.



5 Sam is whirling a ball on a string in a circle above his head. What forces are acting on the ball?



try this

1 Work out a way to measure twisting forces; for example, the force needed to turn a doorknob.
2 Design and build your own forcemeter to measure pushes and pulls. You will need something that returns to its original shape after bending or stretching.
3 The buoyancy force in salt water is much greater than in fresh water. (This means that the upwards force is greater in salt water than in fresh water.) Design a test using a newton spring balance and a mass to show that the buoyancy force is greater in salt water.

Challenge solutions

1 A force of about 20 newtons will lift a container of about two litres of soft drink.
2 This statement is false because the force of the engine is pushing it forward and the forces of friction assisted by the force of gravity are pulling it back.
3 Yes, there are forces acting on the ball while it is in the air. Gravity is pulling it down and the friction with the air is slowing it down. If these forces were not operating we would lose the ball into space forever!
4 Parts of the boat may move or break but it will not move to a different place because there are no external forces acting on it. The boy's feet are pushing in one direction and his hands are pulling in the opposite direction.
5 There is a force towards the centre of the circle, exerted by the string. If the string breaks, the ball flies off at a tangent due to its inertia. There is also a downwards gravitational force on the ball.

4.2 Friction

Friction is an example of a contact force. It occurs whenever two surfaces in contact move past each other.

Friction always opposes motion. Suppose you try to push a bookcase full of books, and it doesn't move. This is because of the friction between the bookcase and the floor. This frictional force is just as large as your push but in the opposite direction. If you get someone to help you, and your combined push is greater than the maximum frictional force, then the bookcase will move.

Even when you do move an object, friction still opposes the motion. Stop pedalling your bike and the frictional forces soon bring you to a stop.

Friction occurs because objects are never completely smooth. The roughness of the two surfaces means there are many points which catch and stick together.

Fig 17 Olympic skiers need to reduce friction to ski as fast as possible downhill. However, some friction between the skis and the snow is needed to allow them to turn quickly.

Investigate
13 MEASURING FRICTION

Aim

To measure the force of friction between different surfaces.

Materials

- large block of hardwood with a hook
- a 5-newton spring balance
- various surfaces (see Step 4)

Surface tested	Force needed to pull block (in newtons)				
	predict	1	2	3	average
desktop					
carpet					

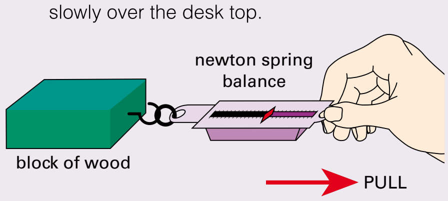
Planning and Safety Check

Read through the experiment and decide who in your group will do what.

Draw up a data table like the one shown.

Method

1 Hook the spring balance on to the block of wood. Use the spring balance to pull the block slowly over the desk top.



Lab notes

It is possible here to introduce datalogging equipment, for example a force meter with a CBL datalogger. An ICT skillsheet on datalogging has been included on the CD.

A variety of spring balances other than a 5-newton one may be required for this investigation.

Learning experiences

1 Ask students to make a list of things that could occur when friction is acting on an object. Examples are heat, sparks, skid marks etc.

2 Investigate different types of friction (rolling, sliding, fluid), when friction can be beneficial and when it is a nuisance, or even dangerous.

Learning experience

Students could write a creative essay, play, song or cartoon strip entitled *What life would be like without friction*. For stories or plays, set a word limit of about 500 words. It needs to be factual (scientifically correct) as well as creative.

2 Measure the force in newtons needed to keep the block moving at a constant slow speed. This force is equal to the opposing frictional force.

Record this reading in your data table.

3 Repeat the measurement and check to see whether it agrees with the first result.

Repeat it a third time, and take an average of the three results. (If you have forgotten how to find an average, see page 25.)

4 Predict the force needed to move the block over other surfaces; for example,
- carpet
- lino
- a concrete path
- a bitumen path
- sandpaper
- the smooth and rough sides of masonite

Record your predictions in the data table.

5 Put the block of wood on each of the surfaces, and record the force needed to move it. (Remember that you need to measure the force three times for each surface, and then find the average.)

Record all your results. How accurate were your predictions?

Discussion

1 Why was it necessary to take three measurements each time, instead of just one?

2 Draw a bar graph of your data.

3 Which surface produced the most friction? Which produced the least?

4 Why does a concrete path produce greater friction than a lino floor?

try this

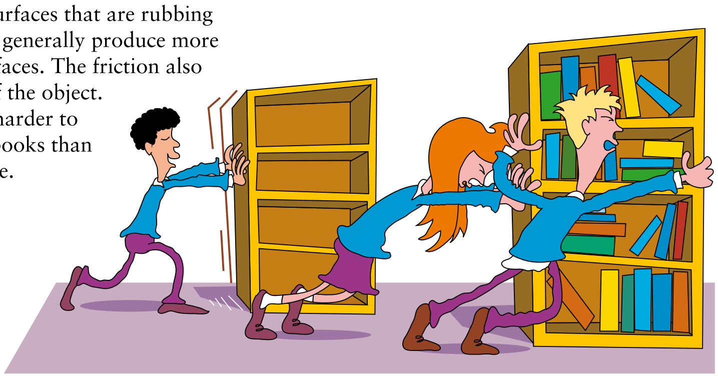
Investigate one or more of the following. Work in a small group to design the investiagtion. Then write a report using the usual headings.

1 How can the frictional force be reduced? You could put pens, pencils, marbles or wooden dowels under the block. Or you could try lubricants; for example, talcum powder, water, liquid detergent or glycerine.

2 What happens to the frictional force if you increase the mass of the block? You can do this by placing blocks on top of each other.

3 How does the area of contact between the block and the surface affect the frictional force?

As you found in Investigate 13, friction depends on the type of surfaces that are rubbing together. Rough surfaces generally produce more friction than smooth surfaces. The friction also depends on the weight of the object. For example, it is much harder to push a bookcase full of books than it is to push an empty one.



Small weight—small friction

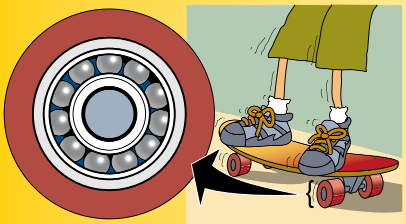
Large weight—large friction

Homework

Students could investigate the forces involved in writing using a ballpoint pen. Ask them to draw a well-labelled diagram showing the forces acting on the pen and paper and to use arrows to show the directions of the forces.

Reducing friction

1 A rolling object meets with less friction than a sliding one. This explains how the ancient Egyptians were able to move the huge blocks needed to make the pyramids by putting logs under them. It is also how ball bearings reduce friction between a wheel and an axle.



2 **Lubricants** (LOO-bri-cants) such as oil and grease are used to reduce friction between the moving parts of machines. For example, the bearings of bicycles and roller blades are oiled or greased to reduce wear and make the wheels turn more easily.

Our bodies, like machines, also have moving parts. Where bones slide over each other at joints there is a lubricating fluid between them to make them slide more easily. If this lubricating system doesn't work properly, you get swelling and pain in your joints. This is called arthritis.

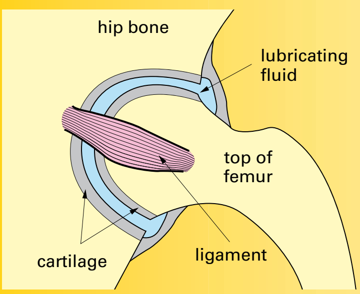


Fig 21 The human hip shows how friction is reduced at joints.

3 Surfaces in contact can be polished so that they slide over one another more easily. For example, the hulls of racing yachts are polished so they slide through the water more easily.

4 If air is blown between two surfaces, the friction becomes very small. This is how a hovercraft works.

5 Air resistance is the friction between a moving object and the air it is moving through. Without air resistance, parachutes would not work and kites would not fly. On the other hand, air resistance can be a nuisance, and modern cars have a streamlined shape to reduce this air resistance. Streamlining is also important for objects moving through water, eg surfboards, speedboats and fast-swimming fish.

Fig 22 Surfboards have a streamlined shape and a very smooth surface to reduce the resistance in water.

Hints and tips

Present to the class a list of lubricants used for reducing friction (graphite, talc, silicon spray).

Assessment task

At the end of this section you could set Assessment task 4: Friction, found on the CD.

Homework

Ask students to describe a day without friction. What would it be like? What would be happening around you?

Learning experience

Explain the term *streamlining*, and ask students to give examples. Explain that this is a way that humans have learnt to overcome friction acting on moving objects. Ask students to give examples of streamlining in nature.

From observing living things, engineers have developed methods to make machines go faster by reducing friction. Ask students to collect pictures of cars, airplanes, surfboards, skateboards etc, showing how streamlining has helped increase the speed of these objects.

Learning experiences

1. Ask students which objects have been designed to reduce air resistance (eg rockets) and which have been designed to increase air resistance (eg parachutes).
2. Set up an air-table or air-track to see what happens to objects experiencing minimal friction. Do the pucks seem like they want to continue moving forever? Why do they eventually stop?

Friction in everyday life

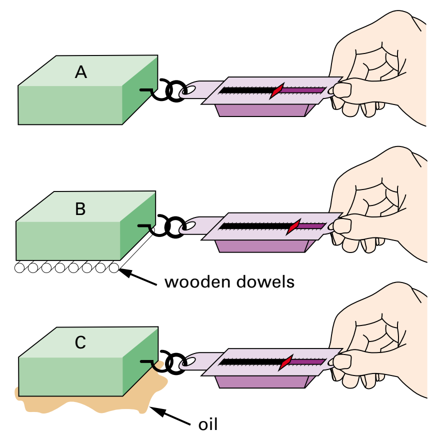
We use friction every day. Sometimes we need friction, and at other times we try to reduce it. When we walk we use the friction between our shoes and the ground. Imagine trying to walk if there was no friction. This would be like walking on ice or a highly polished floor. You could not stop a car without friction. You could not start it moving either—the wheels would just spin without the car moving. And everybody knows what happens if you go too fast around a corner or if the road is slippery. Friction also prevents knots from coming undone, and holds nails and nuts and bolts in place.

Fig 23 Ice has reduced the friction between the tyres and the road surface, making the car spin off the road.

Friction produces heat. This can be useful when you rub a match on the side of a matchbox, but it can cause a car engine to overheat. Friction also causes wear and tear.

Check!

1 Look at the diagrams on the right. Copy and complete the sentences below, selecting the correct word for each.
- **a** Diagram A shows ______ (sliding/rolling) friction.
- **b** The friction in B is ______ (greater/less) than in A.
- **c** Rolling friction is ______ (greater/less) than sliding friction.
- **d** When an object slides, there is ______ (more/less) resistance to movement than when it rolls.
- **e** With lubrication (diagram C) you need ______ (more/less) force to move an object.
- **f** Lubrication ______ (increases/decreases) friction.



Check! solutions

1
- a Diagram A shows **sliding** friction.
- b The friction in B is **less** than in A.
- c Rolling friction is **less** than sliding friction.
- d When an object slides there is **more** resistance to movement than when it rolls.
- e With lubrication you need **less** force to move an object.
- f Lubrication **decreases** friction.

Learning experience

Get students to come up with a list of 'why' questions on friction. Start them off with these examples:

- Why is friction important for car brakes to work properly?
- Is friction only between moving objects or can you have static friction?

These questions could be investigated in class or set as a homework activity.

Learning experience

Ask students to construct a table showing the advantages and disadvantages of friction, briefly explaining each advantage or disadvantage.

This exercise will raise some issues about friction as some students may view an advantage as a disadvantage, or vice versa, depending on the circumstances.

2 Which two factors influence the size of a frictional force?

3 Copy and complete the paragraph below, choosing from these words to fill the gaps:

carpet	force	rough	more
glass	rubs	smooth	less

Things move more easily across a _________ surface than a _____ surface. This is because of friction. It happens when one surface _____ on another. Rough surfaces like _____ produce _____ friction than smooth surfaces like _____ .

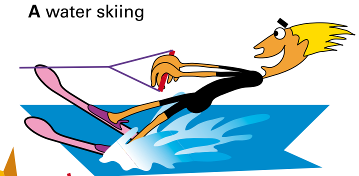
4 Use your knowledge of friction to explain the following.

a Gymnasts put resin on their hands before competing.
b Cars that travel in snow have to carry chains that fit around the tyres.
c Surfers wax their surfboards.
d A car uses more petrol when it is fitted with a roof rack.
e When you drive a car in city traffic for some time the brakes become quite hot.
f The front and underneath of the space shuttle (below) is covered with special heat-resistant tiles.

5 The cartoons below show friction in action. For each example:

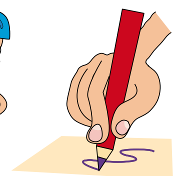
a name the two surfaces between which the friction acts
b say what the force of friction is doing
c say what would happen if the frictional force suddenly disappeared.

A water skiing

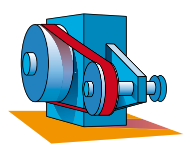


B abseiling

C writing



D using a nail file



E belt driving machinery

F running

6 For each of the following, describe how friction is reduced.

a roller blades
b a water slide
c a jet flying at high speed
d a door hinge
e a bobsled

2 Two factors which influence the size of a frictional force are the type of surfaces and the weight of the object.

3 Things move more easily across a **smooth** surface than a **rough** surface. This is because of friction. It happens when one surface **rubs** on another. Rough surfaces like **carpet** produce **more** friction than smooth surfaces like **glass**.

4 a Resin will increase the friction between the gymnast's hands and the mat or bar.
b Chains will increase the friction, or grip, between the tyres and the snow.
c Wax will increase the friction between the board and the surfer's feet.
d A roof rack will increase the friction with the air and therefore the car will require a greater force to travel at the same speed.
e When brakes are used a lot in heavy traffic the friction creates heat and they become hot.
f Heat resistant tiles are necessary because the friction with the air as the shuttle re-enters the atmosphere produces a lot of heat.

5 Suggested answers are:

Activity	*Two surfaces*	*What the friction does*	*If no friction*
A water skiing	skis and water	skier can stay up	skier would fall off
B abseiling	hands and rope	slows the descent	abseiler would fall
C writing	pencil and paper	marks the paper	pencil would not make a mark
D using a nail file	file and nails	removes some nail	file would not work
E belt driving machinery	pulley and belt	turns the pulley	pulley would slip
F running	shoes and ground	enables you to run	runner would slip and fall over

6 Friction is reduced by:
a using ball bearings in wheels
b water acting as a lubricant between the body and the slide
c an aerodynamic shape
d oil on the pin of the hinge
e the bobsled rails changing solid ice to water which acts as a lubricant.

Challenge solutions

1 The purpose of the tread is to increase the friction between the road and the tyre, particularly in wet conditions. On a wet road the tread forces water out so that it does not act as a lubricant. This enables good contact between the rubber and the road.

2 Suggested reasons are:

a ‘Slicks’ increase surface area and friction on dry surfaces but can ‘aquaplane’ in wet conditions and become very dangerous.

b Friction between the air and the rear wing creates a downward force on the car which increases friction between the tyres and the road.

3 a The frictional force depends on the roughness of the surfaces. The more bumps and hollows, the greater the friction.

b The surfaces are jammed together more for a heavier object than for a light one. Because of this the friction is greater.

4 Whenever energy is changed from one form to another some of it is wasted as heat energy. This is especially so for moving objects where friction causes heat energy to be wasted. This is why a perpetual motion machine cannot work despite some claims otherwise!

challenge

1 What is the purpose of the tread on a tyre? How does it work on a wet road?

2 a Racing cars use ‘slicks’—wide tyres with no tread. Discuss the advantages and disadvantages of these tyres.

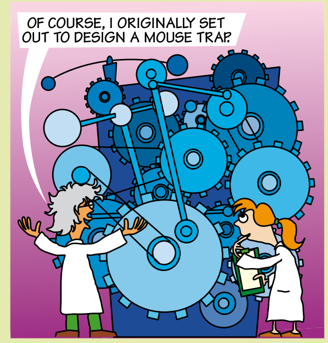
b How does the rear ‘spoiler’ improve the car’s performance?

3 Explain why frictional forces depend on:

a the surfaces in contact

b the weight of the object.

4 The cartoon below shows a perpetual motion machine—a machine that will keep going forever, after an initial force is applied to it. Use what you have learnt in this chapter to explain why such a machine will not work.



WEBwatch

Many people over hundreds of years have been trying to invent perpetual motion machines. Use the internet to find out more about perpetual motion machines.

Go to www.scienceworld.net.au and follow the links to **Museum of hoaxes**.

try this

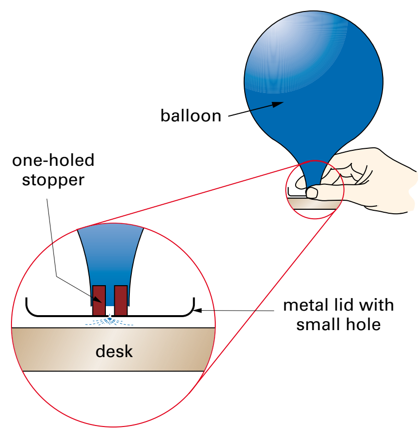
1 Write a short story about a world without friction.

2 Design an experiment to test an oil company’s claim that its brand of engine oil reduces friction more than other brands do.

3 Make a hovercraft from a metal lid with a very small hole in it. Glue a 2 cm one-holed stopper over the hole, as shown on the right. Blow up a balloon (not too much), and hold its neck while you fit it over the stopper.

Now hold the hovercraft on a smooth, level desk, and slowly release your fingers.

Use what you have learnt about forces to explain how the hovercraft works.



Research/assignment

Using the **Museum of hoaxes** website, students could be asked to find a machine that shows perpetual motion. They should explain how it works and who designed it. Does it have everyday applications?

4.3 The pull of gravity

You are sitting at the top of the Tower of Death, a 100 metre tower at the amusement park. The catch is released and you plummet towards the Earth. You and everyone else in the car are being pulled towards the Earth by the force of **gravity**.

Over the centuries people have suggested many inferences to explain gravity. In the 17th century Sir Isaac Newton came to the conclusion that gravity is the force of attraction between objects, and that the size of this force depends on the **mass** of the objects. The mass of an object is the amount of matter in it.

All bits of matter attract each other. There is a force of attraction between you and other people. However, this force is very, very small because the mass of a person is very small.

The greater the masses of the objects, the greater the force between them. You are attracted by the Earth and the Earth is attracted by you. This is why you don't fall off the Earth. But most of the force of attraction is due to the enormous mass of the Earth. Note that this gravitational force acts towards the centre of the Earth.

Spring balances and scales actually measure the force of attraction between an object and the Earth. This is what **weight** is. Because it is a force it is measured in newtons.

Gravitational force is a non-contact force because it exists between objects even when they are not touching. The gravitational force between the Earth and the Moon keeps the Moon in orbit. Similarly, a gravitational force keeps satellites in orbit around the Earth, and all the planets in orbit around the Sun. Gravitational forces can act over the huge distances of space; for example, between stars and between galaxies.

The Moon has less mass than the Earth. This is why gravity is less on the Moon than it is on Earth. If you jumped on the Moon you would not come down as quickly as you do on Earth. Similarly, larger heavier planets like Jupiter have more gravity than smaller lighter planets like Mars.

Fig 32 Gravity on the Moon is only about one-sixth of Earth's gravity. As a result, walking and jumping on the Moon are very different from what they are on Earth.

Hints and tips

The force of gravity depends not only on the mass of each object but also on how far apart the objects are. So although two objects may be massive, if their distance of separation is large, the gravitational force could be quite small.

Homework

- Have students research gravitational forces on different planets or moons.
- Ask students to write a story about the problems they would face if they were weightless. What could they do to overcome these problems?

Learning experience

Take the class outside to show them how a person's balance is affected by their centre of gravity. Demonstrate this by using a plastic witch's hat. The witch's hat is hard to balance on its point because the centre of gravity is high. It is easy to balance on its base because the centre of gravity is lower.

Students can investigate changing their centre of gravity. Ask them to stand on a line in the gym or out in the playground. Get them to:

- stand still on the line
- stand on one leg
- kneel
- repeat all three with their eyes closed.

Allow students to do whatever they need to do to change their centre of gravity, eg stretch out their arms, lean in a particular direction.

Pose the following questions:

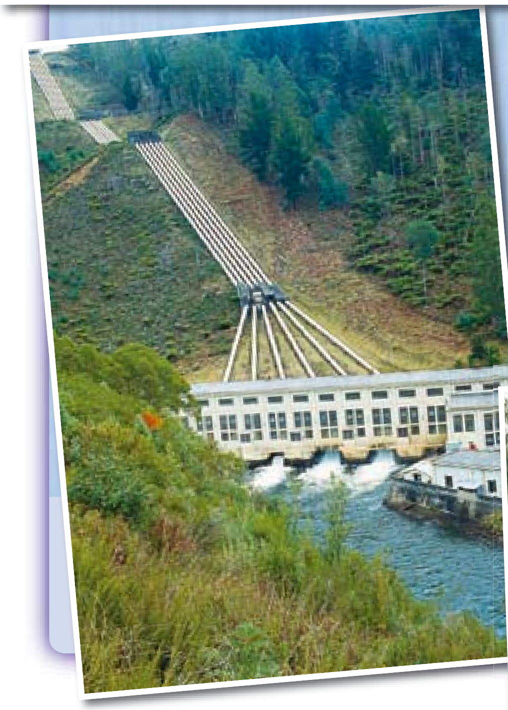
- What did it feel like when you were balanced?
- What did it feel like when you were not balanced?
- When did you feel you had no control?
- What do athletes do to control their centre of gravity?
- Does body shape/type vary the centre of gravity?

Hints and tips

Keen photographers could take their own photos of situations which illustrate gravity acting.

Activity

We use a range of devices to make use of gravitational force. Look at each of the photos and in each case say how we are using gravity.



Learning experience

Once the class has completed the activity on this page, have them brainstorm, in small groups, other events or places where gravitational forces act on objects or people.

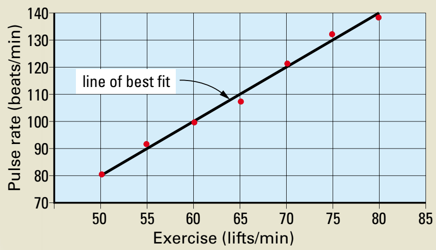
Skillbuilder

Drawing lines of best fit

In the following experiment you are going to hang different masses on a spring. After you take measurements, you are going to plot a line graph of the results.

Graphs are very useful when you are looking for a *pattern* in your results. However, sometimes you have to draw a line of best fit so that you can see this pattern clearly.

For example, in an experiment on fitness, Matthew recorded Sarah's pulse rate and breathing rate. He then plotted the graph below.



Notice that the points lie roughly on the straight line. This is called a straight line of best fit.

Drawing lines of best fit takes practice! The line need not go through all the points. It has to pass close to as many points as possible.

Example

Draw a straight line of best fit for the following data.

Time (days)	Growth of seedlings (cm)
0	0
1	1.0
2	2.1
3	2.6
4	3.8
5	5.0
6	5.8

Experiment

STRETCHING A SPRING

In Chapter 2 you designed an experiment to solve the problem—how quickly can you catch a falling ruler?

This is another experiment in which you have to design tests to solve a problem.

1 The problem to be solved

What happens to the length of a spring when the mass attached to it increases?

2 Designing your experiment

You will be given a spring and some masses. You can use other materials, but you will have to write a list of your requirements to give your teacher.

Work in a small group and decide how you are going to solve the problem. Write a draft of your method, list the materials needed and discuss any safety issues.

3 Results

Design a data table for your results and plot a line graph of the results.

4 Writing your report

Write a full report of the experiment including diagrams where appropriate. In the discussion use the graph to write a generalisation about the mass on the spring and the stretch of the spring.

You could also take a digital photo of your equipment to include in your report.

Use a word processor on a computer to write your report and draw graphs. Working with technology

Lab note

It is important to make students aware that if the spring is stretched beyond its elastic limit it will be permanently stretched. Ask students to ensure that the spring always returns to its original length between measurements.

Have several different springs available.

Research

Students could use the internet to find out about Robert Hooke and to research Hooke's Law.

Science in action

Isaac Newton was born in 1642. His parents lived on a farm in England, and his father died the day before Isaac was born.

Isaac was quite a sickly young child, and very shy. He didn't do very well at school, and he was often bullied by the bright boy in the class. So he worked extra hard until he was the best in the class.

During his boyhood years Isaac liked making things, and he was very good at solving everyday problems. For example, he made a model windmill which was driven by mice running in a treadmill. He also made a water clock and a sundial, and flew kites with lanterns attached to them.

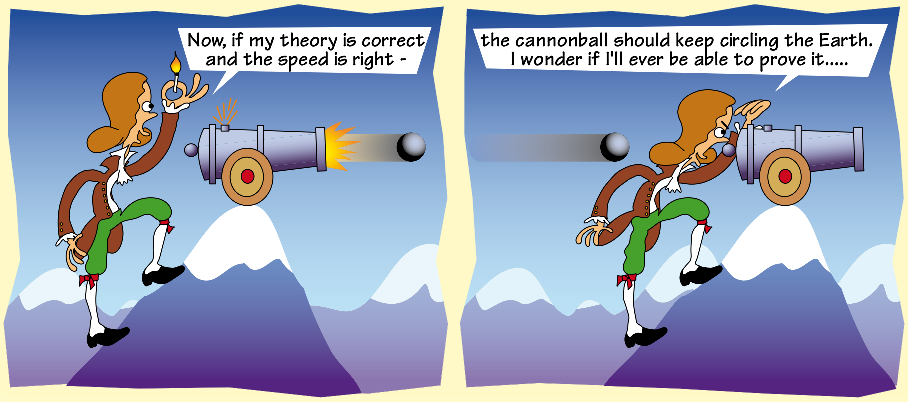
By the time he was 18, Isaac was very interested in mathematics. His uncle said he would make a poor farmer, and talked his mother into sending him to Cambridge University. He did very well there, and when he was 27 he became a professor of mathematics, and made many important discoveries. Perhaps the greatest of these was his theory of gravitation (see page 83). He also passed sunlight through a prism, and found that white light is a mixture of the colours of the rainbow.

Newton had a good imagination. For example, he imagined a very tall mountain from which he could fire a bullet. His idea was that if you could fire the bullet fast enough, it would continue to circle the Earth, just as the Moon does. (Look at the cartoon below.)

One of Newton's faults was that he couldn't take criticism, and he spent a lot of time quarrelling with other scientists. He never married, and throughout his life he avoided publicity. When he was 50 he had a nervous breakdown, and he died at the age of 84. He was the first scientist to be buried in Westminster Abbey in London.

Questions

1 In which century was Isaac Newton born?
2 Did he do well at school?
3 What did he make when he was a boy?
4 What was Newton's greatest discovery?
5 What were Newton's 'good' points and 'bad' points?
6 Use library resources, including the internet, to find out two other things that Newton discovered.



Research

Have students research the contribution that Sir Isaac Newton made to science. They should briefly explain his three laws of motion and how these laws relate to the concepts in this chapter.

Sir Isaac Newton is probably best known and remembered for his observation of an apple falling from a tree. Ask students to find out what important theory supposedly came from this observation and what its importance in science is.

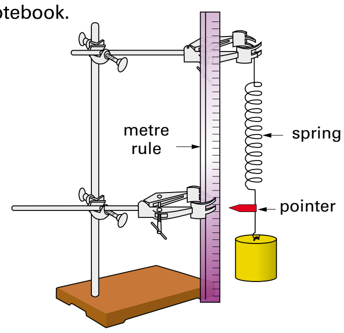
They could write their reports as a series of diary entries as if Sir Isaac Newton himself had written them.

Learning experience

Is the apple story really true? Find some articles about Sir Isaac Newton, particularly about gravity and the apple. Have students read them aloud in class and discuss the articles' merits.

Check!

1 Look at the diagram below. Choose the correct word to complete each sentence in your notebook.



- **a** The force of gravity is a ______ (push/pull).
- **b** A force pulls the spring ______ (up/down).
- **c** The heavier the object, the ______ (less/greater) the force.
- **d** The stronger the force, the ______ (more/less) the spring stretches.
- **e** A 10 N weight is a ______ (larger/smaller) force than a 20 N weight.
- **f** A 20 N force stretches the spring ______ (twice as much/half as much) as a 10 N force.
- **g** Use the data in the table to draw a straight line of best fit. Remember to label the axes and give the graph a title.

Weight (N)	Stretch (cm)
100	8
200	17
300	23
400	32

- **h** Which measurement is the independent one? Give a reason for your answer.
- **i** Using the data in the table or your line graph, predict how much a 50 N weight would stretch the spring.

2 The shop assistant said the bag of apples had a weight of 1 kg.

- **a** Is this correct? What is the weight in newtons?
- **b** If the bag of apples was taken to the Moon, would its mass and weight be the same? Explain your answer.

3 Imagine you are going on a trip to the planets. Your travel agent has given you this table showing the force of gravity on each of the planets.

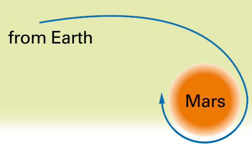
Place	Gravity (compared with Earth)
Mercury	4
Venus	9
Earth	10
Outer space	0
Moon	1.6
Mars	4
Jupiter	25
Saturn	11
Uranus	9
Neptune	11
Pluto	0.7

- **a** Where would you weigh the most? What difference would this make to getting around on the planet?
- **b** Where would you be weightless?
- **c** Suggest why the gravity is similar on Mercury and Mars.
- **d** On which planet would you need the least fuel for blast-off?
- **e** How high can you jump on Earth? Predict how high you would be able to jump on the Moon?

challenge

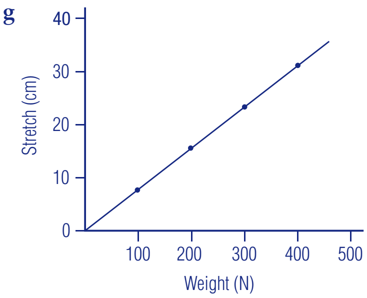
1 The Moon has no atmosphere. Suggest a reason for this. (Hint: Gases such as oxygen have mass, even though the mass is very small compared to a solid.)

2 If a rocket was launched from Earth and travelled close to the planet Mars, it could go into orbit without the rocket engines being fired. How could this happen?



Check! solutions

1
- **a** The force of gravity is a **pull**.
- **b** A force pulls the spring **down**.
- **c** The heavier the object, the **greater** the force.
- **d** The stronger the force, the **more** the spring stretches.
- **e** A 10 N weight is a **smaller** force than a 20 N weight.
- **f** A 20 N force stretches the spring **twice as much** as a 10 N force.
- **g**



- **h** The weight is the independent variable because you choose it and it will cause the spring to stretch (the dependent variable).
- **i** From the graph it can be seen that a 50 N weight will stretch the spring about 4 cm.

2
- **a** Although this happens very often in shops it is not scientifically correct. Mass is measured in kilograms and weight is measured in newtons. A 1 kg mass has a weight of about 10 newtons.
- **b** On the Moon the mass would be the same but the weight, which depends on the force of gravity, would be about 1/6 of that on Earth, or about 1.7 N.

3
- **a** You would weigh most on Jupiter and this would make it very difficult to get around because your body would be about 25 times heavier than on Earth.
- **b** You would be weightless in outer space because there is no gravity acting on your body.
- **c** The force of gravity depends on the mass of the planet. Planets with about the same mass will also have about the same gravity.
- **d** The least fuel needed for blast-off would be on the planet with the lowest force of gravity, which is Pluto.
- **e** You can probably jump about 400 mm high on Earth and should be able to jump about six times as high or 2.4 metres on the Moon.

Challenge solutions

1. The reason for this is that the force of gravity is not great enough to attract and hold the tiny particles of gas which make up the atmosphere.
2. This could happen because as the rocket passes close to Mars the force of attraction due to gravity would draw the rocket into orbit (as shown in the diagram).

Main ideas solutions

1 pulls, direction
2 magnetic
3 unbalanced
4 newtons
5 friction
6 surfaces
7 lubricants
8 gravity
9 weight, mass

MAIN IDEAS

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

1 Forces are pushes or ______. You can use arrows to show their strength and ______.

2 Contact forces act on contact, and non-contact forces (eg ______ forces) act at a distance.

3 The forces on an object may be balanced or unbalanced. If they are ______, the object will start moving, speed up, slow down or change direction.

4 Forces are measured in ______ (N) using spring balances or scales.

5 ______ is a contact force that occurs when two things rub against each other. It slows down or prevents motion.

6 Friction depends on the roughness or smoothness of the ______, and the weight of the object.

7 There are several ways of reducing friction, eg ball bearings, ______ and polishing.

8 ______ is the force of attraction between any two objects, eg between the Sun and a planet. It depends on the masses of the objects.

9 The ______ of an object is the downwards pull of gravity on it. The ______ of an object is the amount of matter in it.

direction
friction
gravity
lubricants
magnetic
mass
newtons
pulls
surfaces
unbalanced
weight

Try doing the Chapter 4 crossword on the CD. Working with technology

REVIEW

1 Match the words with their correct meanings.

force	unit of force
carpet	reduce friction
friction	a pull from a large body
newton	push or pull
gravity	surface with large friction
spring balance	force that exists when one surface rubs on another
lubricants	produced when there is friction
heat	measures force

2 A 1 kg can of baked beans was suspended from a spring balance. The spring balance reading was 9.8 newtons. The can was bought by an astronaut, who took it to the Moon. Here the can was again suspended from the spring balance, and the reading was only 1.6 newtons.

Explain the different readings on the spring balance.

3 Give two examples of contact forces and two examples of non-contact forces.

Review solutions

1

force	push or pull
carpet	surface with large friction
friction	force that exists when one surface rubs on another
newton	unit of force
gravity	a pull from a large body
spring balance	measures force
lubricants	reduce friction
heat	produced when there is friction

2 Gravity on the Moon is only about $1/6$ of what it is on Earth. The mass of the can is still 1 kilogram on the Moon, but its weight (downward pull of gravity) is only $9.8/6$ = 1.6 newtons.

3 *Contact forces*—pushing something with your hand, pulling on a rope, wind blowing, waves crashing on a beach. *Non-contact forces*—two magnets attracting without touching, gravitational and electrostatic forces.

4 A truck has become bogged in mud, and the back wheels are spinning because of a lack of friction. Which of the following actions could help move the bogged vehicle? (There may be more than one answer.)

A put more weight into the back of the truck
B place rubber mats under the wheels
C pour water around the wheels
D let most of the air out of the back tyres

For each action you select, say *why* this would increase the friction.

5 When Kieran stands on some bathroom scales in a stationary lift the reading is 700 N. As the lift descends rapidly what is the reading on the scales likely to be?

A 0 N **C** 700 N
B 600 N **D** 800 N

6 In which of the following situations is friction an advantage, and in which is it a disadvantage? Explain your answers.

a stopping in a hurry
b pushing a fridge across the floor
c running a car engine
d parachuting from a plane

7 A boat floating on still water is said to be under the action of forces that are balanced because:

A the downward force on the boat is greater than the upward force of the water
B the downward force on the boat is the same as the upward force of the water
C the downward force on the boat is less than the upward force of the water.

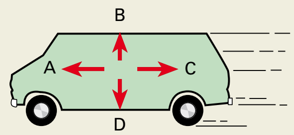
8 Sometimes you want to reduce friction, and sometimes you want to increase it. Explain, using the cartoon as an example.

9 Christina was using a spring balance to measure the force needed to move a block of wood over a number of different surfaces. She measured the force four times for each surface. (See the table below.)

a What was the average force needed to move the block for each of the five surfaces?
b Draw a bar graph of the results (use the average force for each surface).

Surface	Force (in newtons)			
	Trial 1	Trial 2	Trial 3	Trial 4
concrete	20	23	20	18
newspaper	9	8	8	8
vinyl tiles	4	4	3	5
sandpaper	34	32	36	35
grass	16	18	17	19

10 The van is travelling to the left at a constant speed.



a In which direction do the frictional forces slowing down the van act?
b In which direction does the weight of the van act?
c Are the forces on the van balanced? Explain your answer.

11 Lorna hits a tennis ball. What forces are acting on it as it moves across the net? (There may be more than one answer.)

A the force of gravity
B the force of friction
C the force of the hit
D no forces

REVIEW

Check your answers on pages 300–301.

4 **A, B** and **D**

A—the more weight, the more friction

B—more friction between the wheels and the rubber mats than between the wheels and the mud

D—with less air in the tyres there is a greater area of contact between the tyres and the mud, therefore more friction

5 **B**—600 N. In the lift descending rapidly the floor tends to drop from under you and you weigh slightly less.

6 **a** advantage—friction helps slow you down

b disadvantage—friction makes it hard to push

c disadvantage—parts of engine rub together, causing wear

d advantage—friction helps slow you down

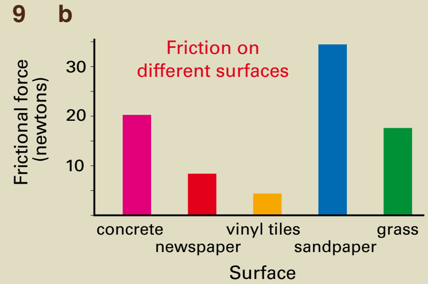
7 **B**

8 When you are skiing, friction can be a nuisance. It is therefore important that the friction between the snow and your skis is as low as possible. This is why you wax and polish your skis. But when you are riding a mountain bike you need as much friction as possible between the snow and the tyres. You would therefore use wide tyres with a thick, rough tread.

9 **a**

	average force (in newtons)
concrete	20.3 $\left(\frac{20 + 23 + 20 + 18}{4}\right)$
newspaper	8.5
vinyl tiles	4.0
sandpaper	34.3
grass	17.5

9 **b**



10 **a** C—opposite to the direction in which the van is moving

b D

c Yes—A and C are balanced, and so are B and D. (The van will therefore keep moving at a constant speed.)

11 **A** (gravity acts on all objects near the Earth) and

B (there is air resistance between the ball and the air).

C is incorrect since the force of the hit acts only at the instant Lorna hits the ball, not as the ball moves across the net.