What you need:
- ramp, jar with a lid

What to do:
1. Roll the empty jar down the ramp.
2. How far did it roll?
3. What made it roll that far?
4. How could you make the jar roll further without changing the ramp?

What if?
- What if the ramp were covered with another material?
- What if the jar were full or half full of water?
- What if the jar were bigger or smaller?
A force is a push or a pull that happens when two objects interact. One object pushes or pulls on another. You cannot see forces, but you can see their effect. Sometimes forces are easy to identify and describe, such as a foot kicking a ball. Other forces are harder to identify and describe; for example, the force that keeps you on the ground.

Figure 7.8
Spring balances are used to measure force.

Forces in action
Forces act on everything around us all the time. Usually, more than one force is acting on any object at one time, but often we do not notice them. You have many forces acting on you at the moment. Gravity is pulling you towards the centre of the Earth. The chair you are sitting on is pushing back against you, changing the shape of your leg muscles. Because these forces acting on you are in balance (the same strength), you do not move. You sit still on the chair.

When you kick or throw a ball, you use energy to create a push force. This force causes the ball to move. When you catch a ball, you are still giving it a push. This time, the push force causes the ball to stop moving.

Forces act on everything around us all the time. Forces cause objects to:

> begin to move
> speed up
> slow down or stop moving
> change direction
> change shape
> remain still.

Examples of these forces are shown in Figures 7.2–7.7.

Measuring forces
One way to ‘see’ a force at work is to measure it. In the kitchen, cooks use scales to measure how much the Earth’s gravity pulls on the ingredients. Twenty grams of flour is pulled to the centre of the Earth, causing the flour to push down on the scales. In the laboratory, force is measured using a spring balance. A stiff spring in the balance stretches when an object pulls on it. This moves the marker so that the amount of force can be measured. A rubber band can measure the size of forces in a similar way to a spring balance.

Before we can use a rubber band to measure a force, it must be calibrated. This means matching the stretch of the rubber band to the force pulling on it. The unit used to measure forces is called a newton after Sir Isaac Newton (1642–1727), who first described the force used to pull an apple from a tree. Spring balances are also sometimes known as newton meters. Scientists around the world have agreed to this standard measurement so that they can communicate with each other. In every country, the force of 100 grams being pulled to the centre of the Earth is about 1 newton (N). This is about the same as one large chocolate bar sitting on your hand.

Figure 7.1 The force of Ronaldo kicking the ball is easy to identify and describe, but what force is pulling him towards the centre of the Earth?
Check your learning 7.1

Remember and understand
1. What is a force?
2. List six things that forces do.
3. How do you measure force?
4. What is the unit of force?
5. Who is the unit of force named after?

Apply and analyse
6. Order these forces from biggest to smallest.
   a. A truck hitting a pole
   b. A rocket being launched
   c. Typing one letter on a computer keyboard
   d. Kicking a soccer ball
   e. Pushing a car along the street

7. Can you see a force? Always, never or sometimes? Explain.
8. Many measuring instruments have to be calibrated. What does this mean? Give an example.
9. A student was using the force measurer in Experiment 7.1 when the rubber band broke. Can a different rubber band be used with the same scale? Explain.
An unbalanced force causes change

Forces always come in pairs. Forces are balanced when they are pushing or pulling equally in opposite directions. If one of the push or pull forces is larger than the other, then the object will change its speed, direction or shape. When this happens, the forces are said to be unbalanced.

Balanced forces

Pushing on a brick wall does not usually cause the brick wall to move. This does not mean your force did not exist. There are many forces around us but most of them do not cause movement. This is because the forces are balanced. If the forces of the two people in Figure 7.9 balance each other, then there is no movement. The people are pushing or pulling with equal and opposite forces. Balanced forces are very important. Two tug-of-war teams will be balanced if they pull with the same amount of force but in opposite directions.

Unbalanced forces

Unbalanced forces are also very important. Consider the forces acting on the barbell in Figure 7.10. The barbell stays up in the air at a particular height because the forces on it are in balance. The weightlifter is pushing the barbell up with exactly the same amount of force as the Earth is pulling down. To move the barbell up, the weightlifter must use a stronger force than the Earth’s pull. This will make the forces on the barbell unbalanced.

Evidence of an unbalanced force

There are three ways you can tell if a force is unbalanced. Forces are unbalanced if there is a change in speed, direction or shape of an object. If a ball is resting on the ground, then all the forces acting on it are balanced. If two people are pushing equally on a stationary object, then the forces are balanced and the object does not move. If one person starts pushing harder, then the object will start to move. There is a change in motion because the forces are unbalanced.

Consider a soccer ball rolling towards the goal. If the goalkeeper kicks it away, then the ball will change direction because the goalkeeper’s kick unbalanced the forces.

Playdough sitting on the bench will not change unless you add a push force with your finger. Your finger unbalances the forces. The evidence for this unbalanced force is a change in shape.
Representing forces

Force diagrams can be represented using an arrow. A short arrow shows a weak force and a long arrow shows a strong force. The direction of the arrow shows the direction of the force. Figure 7.11 shows a tug of war between two teams. The arrows show the pull force they are exerting on the rope. One team is much stronger than the other team. Which team will win? What evidence will you see in real life that this team is stronger?

Forces can be added together

If you tried to lift a heavy object such as a piano, you would not succeed because the upward force you exert on the piano would be too weak. But if a few of your friends helped you by also adding their force to yours, the combined upwards forces would be stronger than the downwards pull of the Earth. The net force is the combination of all the forces acting on the piano. If the piano is lifted up, the forces are unbalanced and the net force on the piano is upward.

If an object is stationary (not moving) or moving at a steady speed in the same direction, then the net force acting on that object is zero. All the forces are balanced. If an object changes its speed (by speeding up or slowing down), shape or direction, then a net force must be acting on it.

Figure 7.11 When forces are unbalanced, a change in motion will occur, with the greatest force ‘winning’. In a game of tug of war, if one team pulls with a force of 200 N to the right and the other team pulls with a force of 300 N to the left, the net force is 100 N to the left. The team on the left will win the game because both teams will move that way. Unbalanced forces lead to a movement in the direction of the greater force.

Check your learning 7.2

Remember and understand

1. What evidence shows that the forces acting on the objects in the following situations are unbalanced?
   a. Pushing down the lever on the toaster
   b. Jumping on a trampoline
   c. A car starts moving

2. When you push against a brick wall, why doesn’t it fall over? Why can a bulldozer push it over?

3. Explain why weightlifters get tired when they hold heavy masses in the air.

4. Give examples where forces cancel each other out (net force = 0) and where two forces add together.

Apply and analyse

5. If Sally can push with 150 N and Marilla with 200 N in the same direction, what force can they push with together? What is the net force if they push in opposite directions?

6. Draw two people having a tug of war. Give them names and draw arrows to show the force they are exerting on the rope. Who is winning?
7.3 Forces can be contact or non-contact

Contact forces involve two objects touching each other. Friction is an example of a contact force and you will learn more about it later in this chapter. If one object is able to push or pull another without touching, it is called a non-contact force. Magnetism and gravity are examples of non-contact forces.

Contact forces
Some forces make objects move because of a direct push or pull. It is much easier to move a pencil if you push it with your finger. Your finger has to touch the pencil or be in contact before the pencil will move. This is called a contact force.

Non-contact forces
Some forces cause movement without touching. These are called non-contact forces. An example of this is the force of attraction between a magnet and a metal paperclip. When a magnet is held next to a metal paperclip, the paperclip is pulled towards the magnet. There is no touching, or contact.

How magnets push and pull
Magnets are made of an alloy (a mixture of metals) that is mostly iron. The bar magnets used most commonly in schools are usually made of the alloy alnico, which is iron mixed with aluminium, nickel and cobalt. New, strong magnets are made from metals known as ‘rare earth’ metals. These are much stronger than normal magnets and do not lose their magnetism.

One end of a magnet is labelled ‘N’ for north and the other end ‘S’ for south. If you hang a bar magnet by a piece of string, then the north end will swing to point north. The magnet is said to have two magnetic poles – north and south.

When the north pole of one magnet is placed near the south pole of another magnet, the two are pulled to each other. This is called
an attraction force. The two unlike poles (a north and a south) attract each other. Magicians use this attraction force to slide something along a table. You can do this too. Place one magnet on top of a thin table and a second magnet under the table. Can you see the pull force? Are the two magnets contacting each other?

When two like poles (two north poles or two south poles) are placed together, they push each other apart. You can use one magnet to push another magnet along a table. This is called a repulsion force. The two magnets do not need to touch to be affected by the repulsion force. It is a non-contact force.

What causes a magnetic force?

An iron needle can become a magnet by sliding a strong magnet along one side of it (in one direction only). The strong magnet pulls tiny groups of particles so that they all line up in one direction. Each time you stroke the needle, these particles line up in the same way, they can pull on a metal pin. Dropping the needle can cause the domains to become mixed up again.

Some magnets never lose their magnetic force. These magnets are called permanent magnets. The domains in these magnets are often arranged while the metal is still buried deep under the ground. Breaking these magnets in half does not change the arrangement of the domains. The two halves become smaller magnets with the same pull or push forces as the larger magnet.

The push forces of magnets are used in the design of futuristic Maglev (magnetic levitation) trains. A series of electronic magnets on the train and track suspend the train above the track. There is no contact between the train and the track. To make the train move, the driver changes the pole of the magnet. When the two magnets on the train and the track have like poles, causing the train to attract the track. The magnets on the train and the track have like poles, causing the train to attract the track. The magnets on the train and the track have like poles, causing the train to attract the track. The magnets on the train and the track have like poles, causing the train to attract the track. The magnets on the train and the track have like poles, causing the train to attract the track. The magnets on the train and the track have like poles, causing the train to attract the track.

Forces

Check your learning 7.3

Remember and understand

1. Name three places where you might find a magnet.
2. Is magnetic force a contact or non-contact force? Explain your answer.
3. Why is one part of a magnet called north?
4. What happens when the following poles of two magnets are pushed close together?
   - a. N and S
   - b. N and N
   - c. S and S
   - d. S and N
5. Draw how you might arrange bar magnets to spell your name. Label the north and south poles of the magnets.
6. Describe how you might levitate a magnetic skateboard above a large magnet on the ground. Mention the arrangement of the poles of the magnet in your description.

Apply and analyse

2. Discuss how you might levitate a magnetic skateboard above a large magnet on the ground. Mention the arrangement of the poles of the magnet in your description.
3. What is the role of magnetic force in the operation of a Maglev train?
4. How can magnetic force be used to levitate an object above a magnet?
The area around a magnet, where magnetic force is experienced, is called a magnetic field. The further away an object moves from the magnet, the weaker the field is. We cannot hear, see or smell a magnetic field but we can see the way a paperclip or another magnet reacts to it. In chapter 8, you will investigate gravitational fields.

### How compasses work

A compass needle is a weak magnet. When a compass is placed near a strong magnet, the compass needle points in the direction of the field. You can see this by moving a compass around the sides and ends of a bar magnet. The north pole of a compass always points to the south pole of a magnet. Iron filings and iron powder are tiny bits of iron. If you put them near a strong magnet, they become temporary magnets. They line up like tiny compass needles around the strong magnet. You can draw this pattern and make a map of the magnetic field.

There is a magnetic field around the Earth. A compass needle will line up with the Earth’s magnetic field. The part of the compass needle with the ‘N’ on it points to the north magnetic pole of the Earth. It is important to note that the ‘geographic’ North Pole of the Earth is not the same as the magnetic North Pole. They are both in the Arctic Circle but hundreds of kilometres apart.

The North Pole, also known as the geographic North or true North Pole, is the northernmost point of Earth. If you tunnelled through the Earth from the North Pole in a straight line, you would come out the other side at the South Pole. The magnetic North Pole is quite different. The magnetic North Pole is not a fixed point – it moves about according to the magnetic field of the Earth and has done so for hundreds of years. This movement is caused by the Earth’s magnetic field. The magnetic South Pole does not always line up with the magnetic North Pole.

### How turtles use the Earth’s magnetic field

When a turtle hatches, it crawls down the beach to the water and swims out to the brightest light on the horizon, which is usually the moon. For the next 30 years, it will swim the fast flowing sea currents around the world. When it is ready, the turtle is able to detect the magnetic field around the Earth. It can measure the direction of the magnetic field (just like a compass) and how strong it is. All it needs to do is follow the magnetic field back to exactly the same beach where it hatched. Once there, it will mate and lay eggs, completing the cycle of life once again.
Flipping the magnetic poles
Throughout history, the magnetic North and South Poles have flipped upside down every now and then. The last flip happened 780,000 years ago. These flips are produced by electric currents inside the Earth and are eventually reversed. The flip takes a few thousand years to complete. While this happens, the poles become very disordered and a magnetic North or South Pole can appear anywhere. How will this affect the turtles being able to find their beach?

Bankcards and magnets
You use magnetic fields in your own life. The black strip on the back of a bankcard has a series of small magnetised zones separated by demagnetised zones. You can see these zones if you sprinkle fine iron filings on them (Figure 7.22). The iron filings arrange themselves according to the magnetic field surrounding the magnetic zones, which look a bit like a bar code. When the card is swiped through a card reader, the magnetic bar code is read and the person’s name, their bank and account number are decoded.

The information on the black strip on a bankcard can be changed if it is put next to a strong magnet. This includes the magnetic clasps on a purse, or wallet. Some stores also attach magnetic security devices to their stock to protect against theft. They remove these using a demagnetiser near the cash register. Leaving a bankcard on a store demagnetiser will also change the magnetic strips on the card.

Check your learning 7.4
Remember and understand
1 What is a magnetic field?
2 How could you map the field around a magnetic nail?
3 Describe in words the shape of the magnetic field when two magnets are:
   a attracting
   b repelling.
4 By looking at the magnetic fields made by different magnets, can you decide which magnet is stronger? Suggest a rule to use.
5 Draw the magnetic field around a broken magnet:
   a that has been re-joined
   b where the two pieces are 10 cm apart
   c where the two pieces are 1 cm apart.

Apply and analyse
6 Explain how a compass works.
7 Explain why you should never leave a library card on the demagnetising panel of a shop.
7.5 Electrostatic forces are non-contact forces

When two objects rub together, there can be a build-up of negative charges on one object. This causes other objects to be pushed away or pulled towards it. This is known as an electrostatic force.

What causes electrostatic force?

Have you ever rubbed a balloon on your hair and seen the hair cling to the balloon? This is a result of another force called electrostatic force. When two objects rub against each other, it causes a small electrical charge to build up. One object becomes positively (+) charged and the other becomes negatively (−) charged. These two charges act like the north and south poles of a magnet. The positively charged objects are pulled, or attracted to, the negatively charged objects. The unlike charges attract. Rubbing the balloon on hair causes the hair to become positively charged and the balloon to become negatively charged. When the (negative charged) balloon moves away, the (positively charged) hair is still attracted to it. The hair lifts up and tries to cling to the balloon (Figure 7.23).

Van de Graaff generators

A Van de Graaff generator works in the same way as rubbing a balloon on hair. In the long shaft of the machine, two long belts rub against one another, making the rounded dome of the machine positively charged. Negative charges are attracted to the dome. If anything comes close enough to the dome, the negative charges attracted and jump through the air. You might see this as a spark (Figure 7.24).

It is not just negatively charged objects that are pulled or attracted to the dome. Uncharged objects (neither positively nor negatively charged) are also attracted to the positively charged dome. If you stand too close to the Van de Graaff generator, your uncharged hair might be attracted to the dome.

Anything touching the dome also becomes positively charged. The girl in Figure 7.25 is standing on a rubber mat so that the negative charges cannot move from the ground into the dome. This means that she becomes positively charged like the dome. Every part of her body becomes positively charged, including all her hair. Just like the forces in a magnet, the like charges in the hair repel each other. This makes the strands of the girl’s hair try to push away from each other.

The rules of electrostatic forces are:

- unlike charges attract
- charged objects attract uncharged objects
- like charges repel.
Electrostatic forces in everyday life

You may have experienced electrostatic forces when you were jumping on the trampoline. Every time you jump, your feet rub against the trampoline mat. This causes a charge to build up in your body. Sometimes this causes your hair to stand up because each strand is pushing away from each other. When you touch someone else, or the framework of the trampoline, you may feel the spark as the negative charges are attracted.

A build-up of electrostatic charge can build up on cars as they drive along the road. It is this charge that can cause explosions when filling up at a petrol station. If the driver gets out of the car without touching the metal of the car, then the car can still have the positive charges built up. It is usually safe to start filling up the car, but if the driver gets in and out of the car (for example, to answer a mobile phone) when the petrol fumes are in the air, the negative charges can be pulled between the car and driver. This causes a spark and an explosion is usually the result. This is the reason why you are not allowed to make mobile phone calls at petrol stations.

Check your learning 7.5

Remember and understand

1. Are electrostatic charges contact or non-contact forces?
2. Describe how electrostatic forces can be created.
3. Finish these statements.
   a. Unlike charges _______________.
   b. ____________ charges repel.
   c. Charged objects ____________ uncharged objects.
4. Explain why the hair of a person touching a Van de Graaff machine may be standing up.

Analyse and apply

5. Isaac was leaving the carpeted library to go home. When he touched the door handle, he received an electric shock. Explain why this happened.
6. When it is about to rain, the water in the clouds rub against one another and an electrostatic charge forms. How does this cause lightning?
Friction slows down moving objects

It is much easier to slide along ice than along a gravel road. This is because the friction of the gravel road acts to slow the forward motion. Friction is the force that resists movement between two objects in contact. In other words, friction slows down moving objects.

What is friction?
When buying sports shoes, many people look for shoes with good grip. This grip prevents the shoe from sliding when they run and helps to avoid sliding when they stop. The grip provides friction between the ground and the wearer. Friction slows everything down that is moving. It acts in the opposite direction to the movement. The greater the friction, the more the movement slows down and eventually stops. Friction happens because objects rub together. When you start walking, you rely on the shoe rubbing against the ground so that you can push forward. When you try to stop, you rely on the friction between the shoe and the ground to stop your movement. Without friction, your feet would just slip over the ground. It would be like trying to walk on ice.

Evidence of friction
We can see evidence of friction in many parts of our lives. Any time a movement is slowed down, it is because of friction. Without friction, a bike would keep rolling along a road without the need to pedal. A pen or pencil would slide over a page without leaving a mark. Friction is very useful to us, but it can create problems and we often try to reduce it.

How to decrease friction
Rollers or balls are one way to reduce friction. Because the balls roll across the ground, it is much easier than being dragged along. Tiny balls are often used as bearings to allow two surfaces to slide over one another easily.

Hovercrafts and air pucks have low friction because they use a layer of air to glide over a surface. There is no contact between the surfaces and as a result,
almost no friction. The same idea is used in magnetic levitation (Maglev) trains, where the trains and carriages are held above the tracks by strong magnetic forces.

Lubricants, such as oils and grease, also reduce friction. This is called lubrication. If a kitchen drawer sticks, you can use candle wax or soap as a lubricant. Lubricants work by coating the surface with an oily or waxy substance, which makes them slippery. Putting oil on bicycle chains and grease on the wheel axles makes the wheels spin more easily, with less friction.

Air resistance, or drag, is the friction between a moving object and the air it is moving through. Air resistance limits the speed of an object in the air. Air resistance is necessary for parachutes but it is a problem for cars and trucks. Streamlining (makes the surface smooth and rounded) helps overcome air resistance (Figure 7.29).

Fish and sharks have streamlined bodies. This allows them to move through the water with the least amount of friction.

Check your learning 7.6
1 List three examples where friction is useful and three examples where friction is a problem.
2 Why is a penguin streamlined, but a sea anemone is not?
3 Why do surfers wax their surfboards?
4 Why does the tread on the tyres of your bike wear down over time? Explain this in terms of force.
5 A hovercraft moves across water on a cushion of air. What is the benefit of this?
6 In a world without friction, what would happen if you tried to:
   a go down a slide in a playground?
   b play tenpin bowling?
   c tie your shoelaces?
7 How are speed and friction related?
8 If you used the same pushing force in each case, over which surface would an object move the fastest: sand, wood, or metal coated in oil? Explain your answer.
7.7 Simple machines decrease the amount of effort needed to do work

The ancient Egyptians, Romans and Greeks understood forces very well. They made simple machines that helped them build the pyramids, fight wars and build cities. The simplest machine they used was a lever. A lever is a simple machine that can be used to decrease the amount of effort needed to do work. You use levers every day. They include scissors, pliers, brooms, shovels, wheelbarrows and can openers.

Figure 7.30 Ancient Egyptians used round logs and rope to haul large blocks of stone when they built the pyramids.

Levers

A lever is a solid rod or bar that is supported at a turning point called a fulcrum. Figure 7.32 shows the main features of a simple lever — a see-saw. The force used to operate a lever is called the effort, and the resisting force it overcomes is called the load.

When one person on the see-saw is pulled down by the Earth, the other person is pushed up. The weight of the two people does not need to be equal for this see-saw lever to work. One person can lift a heavier weight by moving further away from the fulcrum in the middle. In fact, the effort of one person can lift a load of two people if the single person is twice the distance from the fulcrum as the two person load.

Mechanical advantage

The lever gives you a mechanical advantage. The size of the advantage can be calculated by dividing the size of the load by the size of the effort:

\[ \text{Mechanical load} = \frac{\text{size of the load}}{\text{size of the effort}} \]

The magnification of the force comes with a disadvantage. For this type of lever, the effort must move a greater distance than that of the load.

These levers are called force magnifiers. They can change a weak force into a stronger...
force. A crowbar can be used to lift a heavy rock even though the distance the effort travels will be much larger than the rock moves.

Other levers are **distance magnifiers**. They can change a strong force that acts over a short distance into a weak force that acts over a longer distance. An example of this is a tennis racket. The end of the tennis racket moves a greater distance than the hand holding the racket.

### Types of levers

There are three types of levers that are classified according to the position of the fulcrum (turning point).

- **First-class lever**: the fulcrum is between the effort and the load (EFL)
- **Second-class lever**: the load is between the effort and the fulcrum (ELF)
- **Third-class lever**: the effort is between the load and the fulcrum (LEF)

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**Check your learning 7.7**

**Remember and understand**

1. Look at Figure 7.36.
   a. What type of lever is shown?
   b. Would an effort of less than 200 kg be able to lift the load?
   c. How would you reposition the fulcrum so that a weight much less than 200 kg can lift the load?

2. A crowbar (see Figure 7.37) can be used to move a load.
   a. What class of lever is it?
   b. Is this class of lever a force or distance magnifier? Explain your answer.

3. Modern cranes use leverage to lift heavy objects (see Figure 7.38).
   a. Where is the load located?
   b. Where is the effort located?
   c. Where is the fulcrum for this lever?
   d. What class of lever is this?
   e. Is this lever designed to magnify force or distance? Explain your answer.
A pulley changes the size or direction of force

A pulley is a simple machine that makes it easier to lift an object. Pulleys are wheels with a groove along their edge. The wheel is used to change the size or direction of the force used.

History of the pulley

Between the 15th and 17th centuries, a period known as the Age of Discovery, the people of Europe were desperate for spices, gold and silver. Sailors navigated the seas looking for these treasures. They returned with large amounts of bounty that included food, weapons and slaves. All this cargo needed to be loaded on and off the ships as quickly as possible. To help the sailors do this work, they used a simple machine invented by Archimedes many centuries before.

![Figure 7.39 The simplest pulley system is made of one pulley.](image)

Types of pulley over two lines of

The simplest pulley system is made of one pulley. This system only changes the direction of the applied force, not the size of the force. As a person pulls down on the rope, the weight on the other end moves up. This doesn’t change the amount of effort needed, but it makes lifting easier. This is because the person can use their weight to help in the lifting. You have probably used this type of pulley when you pull the cord to open a window blind at home. The mechanical advantage is calculated by the number of ropes between the upper and lower pulleys; in the roller blind system it is one.

The more pulleys that are used, the easier it is to lift a load because its mechanical advantage is increased. For example, if two pulleys are used, then the system can lift twice the load of a single-pulley system. The mechanical advantage of this system is two (Figure 7.42).

A four-pulley system can magnify the effect of the effort four times. For example, a 25 kilogram object can lift a 100 kilogram load in a frictionless pulley system. The simple system shown in Figure 7.43 not only changes the direction of the applied force, it also multiplies it by four. This system has a mechanical advantage of four.

Groups of pulleys are often mounted together in a frame or ‘block’. This device is called a block and tackle (Figure 7.44). A small effort pulling through a long distance lifts a large load through a much smaller distance.

![Figure 7.40 Sailing ships have pulley systems for lifting heavy sails and cargo.](image)
Figure 7.41 A single-pulley system. Rope is guided through the grooves of a set of rotating wheels.

Figure 7.42 A two-pulley system doubles the mechanical advantage.

Figure 7.43 A four-pulley system increases the mechanical advantage by a factor of four.

Figure 7.44 This block-and-tackle system is used to lift heavy objects.

Check your learning 7.8

Remember and understand
1. Why are two pulleys better than one?
2. A block and tackle provides a mechanical advantage because it can lift heavy loads. Does it have any disadvantages?
3. Give three examples of where single pulleys or pulley systems are used.
4. Describe how pulleys made loading and sailing huge cargo vessels possible.
5. Choose the correct option. A pulley system can:
   a. increase force and distance at the same time
   b. decrease distance while increasing force
   c. decrease force and distance at the same time
   d. change the direction of motion.

Analyse and apply
6. A 100 kg mass is used to lift an 800 kg mass.
   a. How many pulleys are needed?
   b. What is the mechanical advantage of this machine?
Many different machines have been developed through the centuries that make less work for us. Famous mathematician Archimedes developed a screw that carried water to the top of a house. The screw was just a hollow pipe with an inclined plane (a simple machine) wound around the inside.

As well as pulleys and ramps, other simple machines are ramps, wedges, screws and wheel and axles.

Ramps
Ramps are the simplest types of inclined planes. A ramp is used to lift heavy objects up to a higher level. For example, a piano mover might use a ramp to get a piano from the ground onto a truck. Ramps are used to bridge gaps between uneven surfaces. Escalators are moving ramps with steps (Figure 7.45). A ramp is called a simple machine because it makes moving a load easier. Going up the ramp might take longer than a single step up, but it takes a lot less force from your legs.

Wedges
A wedge is an inclined plane that moves through another object and changes the direction of a downwards force to a sideways force. An axe is a wedge. When an axe hits a log, the downwards force is changed to a sideways force, which splits the log (Figure 7.46).

Humans discovered the benefits of the wedge when they used the jagged edges of rocks to cut animal flesh and skin. It is more than likely that you have used a wedge today: a knife is a wedge and so are your teeth. Each tooth in a zipper is a tiny wedge that fits tightly with the adjacent teeth.
Screws

You might be surprised to know that a screw, like the wedge or ramp, is also an inclined plane. The indent that spirals around a screw, called the thread, looks almost like a road (a ramp) spiralling up the side of a mountain. Screws penetrate materials such as wood or cork by using the turning effect of a force. The effort needed to turn a screw into an object is much less than hammering a screw into the same object.

Wheel and axles

If you've used a circular door handle or travelled in a car, bus or train today, then you have used a wheel and axle simple machine. A wheel is a type of lever that turns in circles about its centre – the fulcrum or pivot point. An axle usually links the lever and the wheel. For example, when you turn a doorknob you apply an effort force to the door handle and the axle exerts a force on the load (the latch), which opens the door.

A wheel and axle is sometimes a force magnifier. For example, you apply a small effort to a doorknob to move a larger load, the latch. This is because the outside edge of the wheel, or doorknob, moves a larger distance than the axle, or latch. A Ferris wheel is an example of a wheel and axle (Figure 7.48).

Wheel and axle machines can also act as distance magnifiers. When you pedal a bike, you apply a force to the pedals. This force causes the larger wheels to turn. The distance the wheel travels is much further than the distance the pedal travels. The distance has been magnified.

Check your learning 7.9

1. List the six types of simple machine.
2. Are any of the six simple machines similar? Explain your answer.
3. Which one of the following is not considered an inclined plane?
   a. A knife used to cut bread
   b. A screwdriver used to turn a screw
   c. A nail driven into a piece of wood
   d. A spear thrust into a tree
4. Which part of a circular doorknob is the wheel and which part is the axle?
5. Is a circular doorknob a force magnifier or a distance magnifier?
6. Is the can opener shown in Figure 7.50 acting as a wheel and axle? Explain how it works.
Many athletes dream of winning Olympic gold medals. They train for long periods, control what they eat and make sure they have the best equipment available. Having a good understanding of the forces involved in their sport can give the athlete an advantage over their competitor.

**Forces in swimming**

A swimmer must have a good understanding of how the water moves around them to maximise their speed. First, they must control how they dive into the water. Breaking the water’s surface creates friction and can slow them down. So they must make sure their whole body enters the water in the same place that their hands originally broke the surface.

Many swimmers shave all their body hair before a big competition. A smooth surface allows the water to move along their body with less friction.

The swimmer’s position in the water is important. If the body is straight, the water moves along without interruption. If the legs hang down, the moving water must change direction. This creates more friction and slows the swimmer down.

In 2012 FINA (Fédération Internationale de Natation), the international governing body of swimming, banned the use of full body smart suits (Figure 7.51).

These suits were designed by scientists to reduce the friction between the swimmer and the water. The suits were made of a material that mimicked the small scales on a shark. This material repelled the water rather than absorbed it, making it lighter for the swimmer to wear. It also reduced the friction between the swimmer and the water. The suits were also designed to be very tight with smooth seams. This helped the swimmer be more streamlined in the water.

Many world records were broken when this suit was first used but FINA decided that it gave an unfair advantage to the countries that could afford this expensive technology. New rules were drawn up that limited the type of swimming costumes that could be worn in high-level swimming competition.

**Forces in tennis**

The human arm acts as a third-class lever where the shoulder is the fulcrum, the muscle attached to the middle of the upper arm provides the effort and the load is usually near the hand. A tennis racquet acts as an extension of the player’s arm. This increases the distance between the load (where the tennis ball hits) and the fulcrum. Third-class levers are speed multipliers as well as distance multipliers.

When a player hits the tennis ball with a racquet, the speed of the ball is increased. If the tennis player’s arm is bent, the end of the racquet is travelling slower, and therefore the ball will rebound slower.

Tennis players will often have longer tennis racquets, not to increase their ability to reach for the ball, but to increase the speed at which they can hit the ball.
Forces in golf

The benefit of a dimpled surface on a golf ball is now widely known. However, golf balls originally had smooth surfaces. When golfers noticed that their old and battered golf balls flew further than the newer, smoother balls, a group of scientists investigated why this occurred.

The dents and bumps in an old golf ball cause the layer of air next to the ball to stay close to the ball, moving in an organised way over the surface. This decreases the overall air resistance of the ball moving through the air, making it fly further. As a result, a golf manufacturer started making the ‘pre-dented’ golf balls that you see today.

Extend your understanding

1. Choose a sport in which you regularly participate.
2. List the forces and the machines involved in your sport.
3. Give an example of how these forces and machines interact in your chosen sport. When are the forces balanced or unbalanced? What evidence do you have that the forces are unbalanced?
4. Explain how you could maximise or minimise these forces in order to achieve better results in the sport.
Remember and understand

1. Think back to the start of your day. Describe the forces that you experienced from the time you got up, to the time you arrived at school.

2. Copy and complete the following sentences.
   a. A force is a _______ or a _______ between _______ objects.
   b. To measure a force, you can use a ____________ ________.
   c. The unit used to measure forces is called the _______. Its symbol is _______. The weight force of 50 g is about _______ newtons.
   d. When an object is not moving, its forces are said to be _______. Evidence of an unbalanced force is a change in ________, ________, or ________.

3. Which of the following involve forces, and which do not? Explain.
   a. Opening a window
   b. Turning a screw with a screwdriver
   c. Smelling food cooking
   d. Moulding clay
   e. Standing on a diving board
   f. Watching a candle burn

4. How is mechanical advantage calculated?

5. What is the difference between a contact force and a non-contact force? Give an example of each.

Apply

6. Explain the following in terms of friction.
   a. Gymnasts put chalk on their hands.
   b. People driving cars on ice or snow put chains on their tyres.
   c. A car uses more petrol when it has a load on the roof.
   d. It is hard to run on ice.

7. Investigate the action of an Olympic shot-putter.
   a. Why does the athlete bend backwards just before releasing the shot?
   b. What class of lever is formed by the upper torso?

Analyse and evaluate

8. Think about how far a toy car and a marble would roll along a flat bench. Which has the least friction? Which rolls the furthest? What is the connection between rolling and friction?

9. Consider the pulley system in Figure 7.XX. How far will the 100 kg load rise if 2 m of rope is pulled through the pulleys?
10 Figure 7.54 shows what happens when you stand on your toes.
   a What type of lever is formed by the foot when you do this?
   b Discuss why this lever is a force magnifier.

11 Investigate the kicking action of a soccer player.
   a Draw a picture of a leg kicking a ball. On your diagram identify which of the muscles are involved in moving the food.
   b What class of lever is formed by the muscle and bone attachments?
   c Are they force magnifiers or distance magnifiers?

Critical and creative thinking

12 Suppose Matilda fills her car with petrol and drives 100 km along a freeway. She then turns off the freeway and travels 100 km along country roads, one of which is very rough.
   a Which part of the trip would the car use the most petrol?
   b Explain your answer using your knowledge of forces and friction.

Review

13 Forces are needed to keep cells together, to pump blood around the body and to move our muscles. Research the different forces in the human body and how they work. Present your findings as a poster.

14 Musical instruments often use simple machines. For instance, levers are used in pianos. Consider the following questions as part of your research:
   a How are levers used in pianos?
   b Which other musical instruments use levers?
   c How does the lever help make sounds?

15 The wearing of seatbelts in a car was first made law in Australia in 1970. Research the materials that are used to make seatbelts. Use your knowledge of forces to explain how seatbelts prevent injury in a car accident.

16 Even though Leonardo da Vinci lived long before the Industrial Revolution, he designed numerous machines. Some of these machines were designed for civil purposes and some for military purposes. Find out about some of the machines. What types of simple machine did he use in his designs? Have any of his machines become a reality? What factors might have prevented his machines becoming a reality?