CHAPTER 3

Machines everywhere

You will discover

What a simple machine is

How simple machines can multiply your effort or your speed

How simple machines work together as part of more complicated machines

Machines from the past

Flying high — trick machines

Imagine you're about to catch some serious air or you're jamming through the dirt in a high-speed BMX race. Maybe you're about to commit to a tail-end transfer or a backflip barspin. You could be doing it hard in the uphill leg of a road race or going through your paces in a velodrome, or just getting around town on your wheels.

Your bike is a machine that can get you going fast enough to do some major tricks. It can help you up a backbreaking hill or just make it easier to get to the local shops. A bike is a machine, but it is actually made up of many simpler machines.

1 How does a bike get me going faster?

2 How does a bike tackle hills?

3 What simple machines are found in bikes?

In the garden

It would be difficult to move a pile of rocks from one end of the garden to the other by hand. It takes much less **effort** using a wheelbarrow. The effort you use is actually a **force**.

Sometimes, even your biggest effort isn't enough to move some very heavy objects. Moving objects can be made easier with simple machines. Simple machines can multiply your effort, change the direction of your effort or make things go faster.

One type of simple machine is the **lever**.

Using levers

A lever is usually a long, rigid object that moves around a turning point called a **fulcrum**. You need to put in an effort to make the lever move a **load**. Levers are named according to where the fulcrum, load and effort are positioned along the lever.

First-class levers

First-class levers, such as the shovel, secateurs and shears below, turn around a fulcrum that is between the effort and the load. All first-class levers are **force multipliers**. They magnify your effort. This means that you may be able to move loads that you couldn't move without the lever.

Second-class levers

Second-class levers are also force multipliers. They turn around a fulcrum that is at the end of the lever. For second-class levers, the load is always between the effort and the fulcrum.

The wheelbarrow is a second-class lever. It is used to move objects that would otherwise be too heavy to carry. The *load* in a wheelbarrow is between the fulcrum and the effort.

Activities

REMEMBER

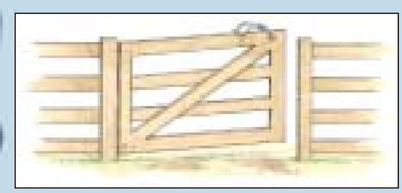
1. What do you call the force you apply to a lever to move an object?
2. Explain how a first-class lever is different from a second-class lever.
3. Why are first- and second-class levers called force multipliers?

THINK

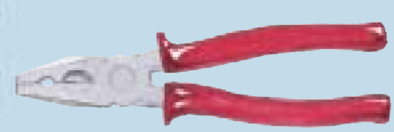
4. Two wheelbarrows are identical, except for the length of their handles. Which would you prefer to use? Why?
5. Sketch and label the effort, fulcrum and load in each of the following diagrams. State whether each is a first- or second-class lever.

(a)

(b)



(c)



checklist

I can:
- ☐ compare first- and second-class levers
- ☐ identify the effort, fulcrum and load in a lever system.

Living levers

The long bones in our arms and legs act as **levers**.

Our joints form fulcrums and our muscles apply a **force** to the bones to make them work. Many of the levers in our bodies are **third-class levers**.

Third-class levers are those in which the effort is between the fulcrum and the load. All third-class levers are **speed multipliers**. A big effort needs to be applied, but the load moves over a greater distance, at a higher speed.

Some sports make use of more than one type of simple machine. Woodchopping uses the arm and axe together as a third-class lever. The axe blade strikes the wood block at a high speed. The blade itself is another simple machine called a **wedge**. A wedge pushes objects apart. In this case, the axe blade splits the piece of wood into two parts.

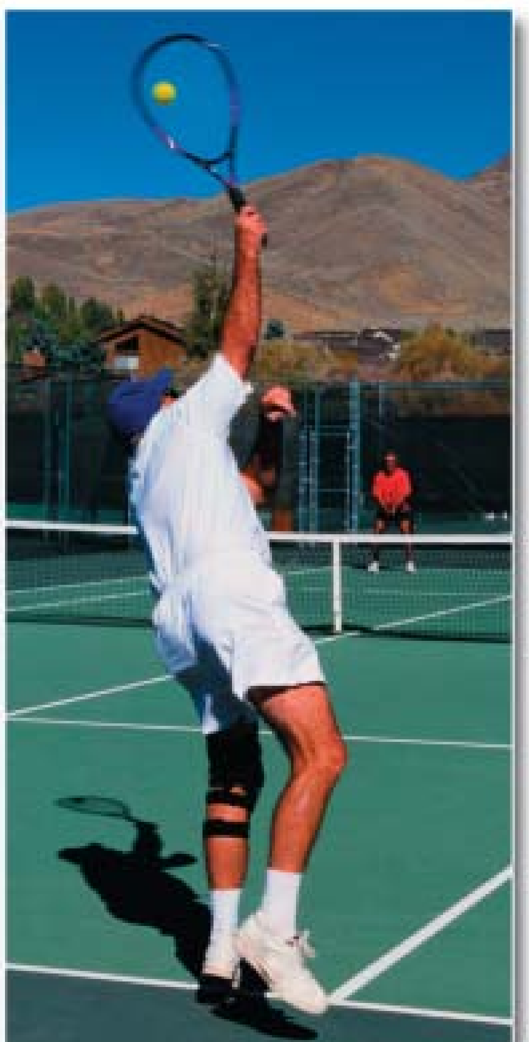
The leg below is acting as a third-class lever. The effort is between the fulcrum and the load.

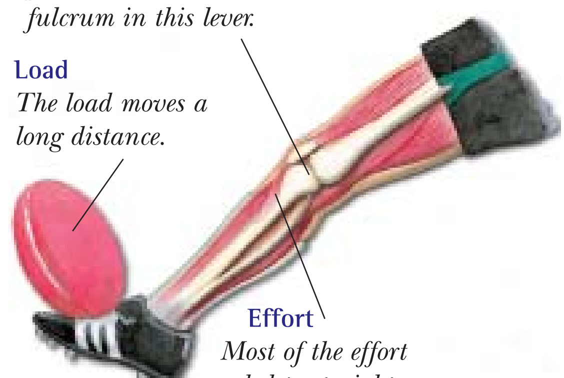
HOW ABOUT THAT! Levers in sport

In sport, levers are usually used to increase the speed of a load and the distance over which it travels. Tennis racquets, cricket bats and softball bats are all third-class levers. They are used to make objects move faster and further.

The longer the distance between the load and the effort, the faster the load will move. Tennis players reach up high when they serve. This way, the lever formed by the arm and the racquet is much longer.

A fast serve can measure over 200 km/h. Greg Rusedski has served at a speed of 239.8 km/h. Mark Philippoussis has served up to 226.9 km/h.





Fulcrum
The lower part of the footballer's leg pivots around the knee. The knee is the fulcrum in this lever.

Load
The load moves a long distance.

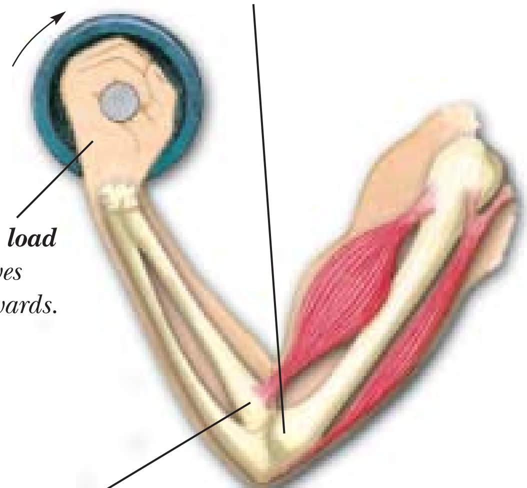
Effort
Most of the effort needed to straighten your leg when kicking a ball comes from the muscles in your legs. The effort to kick a ball is applied from muscles that attach to the top of your lower leg.

Different classes of lever in the arm

Bending and straightening the arm uses two different classes of levers.

Bending the arm

The elbow is the ***fulcrum*** *because it forms the pivot point for the movement of the arm.*

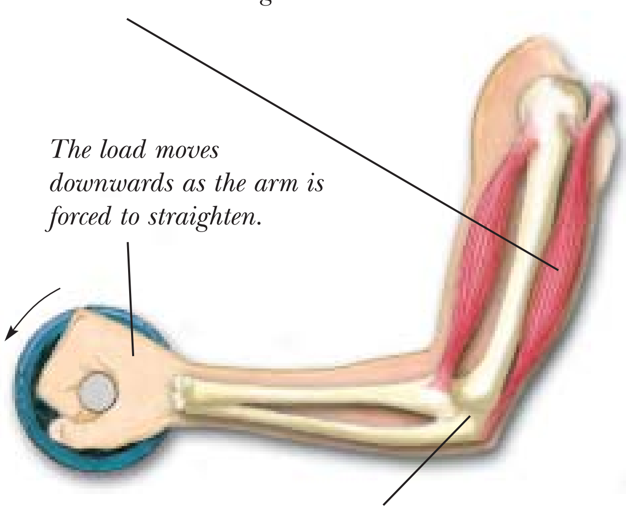


The ***load*** *moves upwards.*

The forearm provides the ***effort*** *through its connection to the biceps muscle below the elbow. Therefore, the effort is between the fulcrum and the load, making the forearm into a third-class lever.*

Straightening the arm

This muscle is called the triceps muscle. It provides the effort used to straighten the arm. You use your triceps muscle when you push a heavy load down. The triceps are also used to shoot goals in basketball and netball.



The load moves downwards as the arm is forced to straighten.

The triceps muscle attaches to the elbow, which is the fulcrum. The fulcrum is between the effort and the load, so your forearm acts as a ***first-class lever.***

Activities

REMEMBER

1. Explain how third-class levers are different from first- and second-class levers.
2. (a) Label the effort, fulcrum and load along the fishing rod.
   (b) What class of lever does the fishing rod act as?

THINK

Some sports, like rowing, do not rely on speed alone. It is very difficult to move through water, so a **force multiplier** is needed to help the rowers.

3. (a) What class of lever do these oars form?
   (b) What other sports use force-multiplying levers?
4. Do you think that humans are built for speed or for strength? Explain your answer.

INVESTIGATE

5. Choose a sport not already mentioned on this page.
   (a) Explain how levers are used in this sport.
   (b) What classes of levers are used?
   (c) Why are these types of levers used?
   (d) Draw a labelled diagram to show how the levers are used in your chosen sport.

✓ checklist

I can:
- ☐ distinguish between speed-multiplying levers and force-multiplying levers
- ☐ explain how levers are used in a variety of sports.

Playing with machines

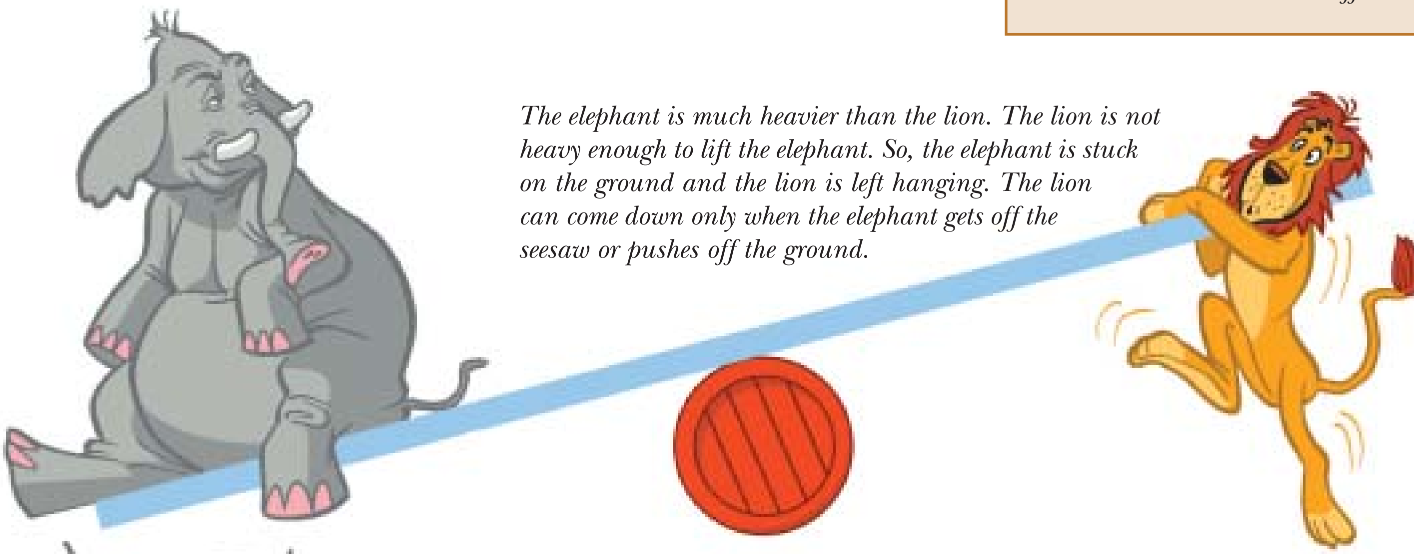
A seesaw can be a lot of fun if the two people on it are about the same size. A seesaw works best this way because both people need to apply the same **effort** to make the seesaw work. On an unbalanced seesaw, one person is left to do all the work.

Placing the fulcrum

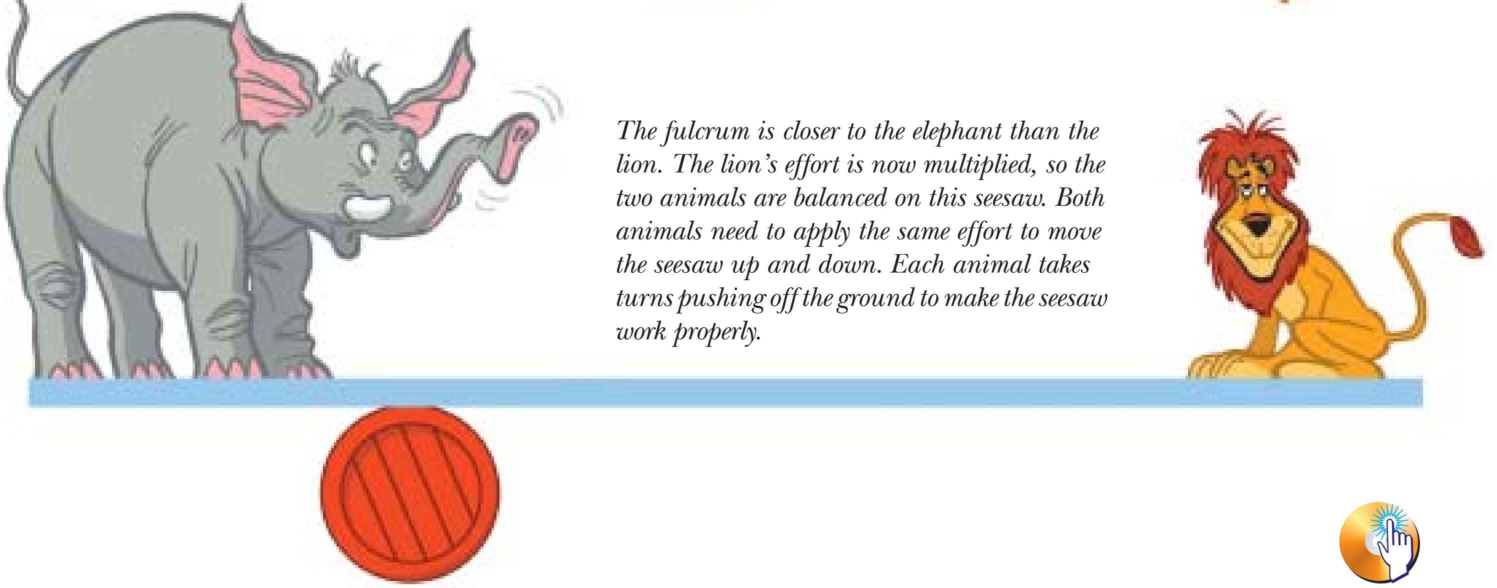
A seesaw is a special type of **first-class lever**. The **fulcrum** of a seesaw is usually exactly in the middle of the effort and the **load**. The two people on a seesaw take turns in being the effort and the load, depending on their movement. First-class levers are **force multipliers**, so a small person *should* be able to lift a larger person on a seesaw without using much effort.

Mechanical advantage measures how much easier a lever makes a task. Mechanical advantage is calculated by dividing the load by the effort. In the example of the seesaw, the effort of the lion was able to lift the elephant. The mechanical advantage in this case is the weight of the elephant divided by the weight of the lion.

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$



The elephant is much heavier than the lion. The lion is not heavy enough to lift the elephant. So, the elephant is stuck on the ground and the lion is left hanging. The lion can come down only when the elephant gets off the seesaw or pushes off the ground.

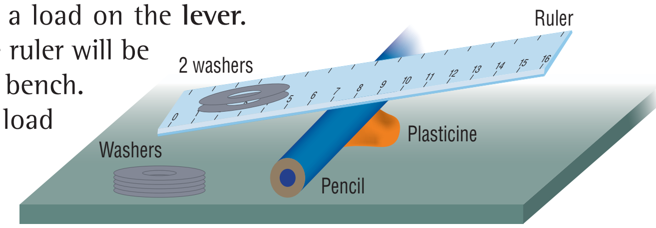


The fulcrum is closer to the elephant than the lion. The lion's effort is now multiplied, so the two animals are balanced on this seesaw. Both animals need to apply the same effort to move the seesaw up and down. Each animal takes turns pushing off the ground to make the seesaw work properly.

Balancing a lever

You will need:
30 cm ruler
pencil or triangular piece of wood in the shape of a prism
plasticine
6 identical washers.

- Set up the ruler with the pencil or wood as a fulcrum. The fulcrum needs to be exactly in the centre of the ruler.
- Use the plasticine to attach the pencil to the bench.
- Place two of the washers 5 cm from the fulcrum. These washers act as a load on the **lever.** The end of the ruler will be resting on the bench.



- Try lifting the load by using two washers placed close to the fulcrum. Slide the washers away from the fulcrum in the opposite direction of the load, until they *just* lift the load. These washers act as the effort in the lever system. What is the closest distance between the effort and the fulcrum that allows you to lift the load washers?

Record your results in a table like this one:

Number of washers used as the load	2	2	3	4
Distance between the load and the fulcrum (cm)	5	5	5	5
Number of washers used as the effort	2	1	1	2
Distance between the effort and the fulcrum (cm)				
Mechanical advantage (load/effort)				

- Remove the two effort washers. Now use just one of the washers to lift the original two load washers. Record the smallest distance between the effort and the fulcrum that allows you to *just* lift the load washers.
- Predict where a washer needs to be placed if the load is increased to three washers. Record your prediction.

1. Test your prediction and record your results.

- Increase the load to four washers. Use two washers as the effort to just lift the load. Record your results.

2. Look for patterns in your table of results. Write a simple rule that explains how to place the effort washers so that they *just* lift the load washers.
3. Predict the largest load that you could lift with an effort of just one washer. Borrow some identical washers from another group and test your prediction.
4. Was your prediction correct? If not, explain why.
5. What happens to mechanical advantage when the distance between the effort and the fulcrum is increased?

Go to worksheet 11

MI LOGICAL/MATHEMATICAL

Activities

REMEMBER

1. True or false?
   (a) First-class levers have the load between the fulcrum and the effort.
   (b) Levers are better force multipliers when the fulcrum is closest to the load.
   (c) Only people of the same size can balance out a seesaw.

THINK

2. (a) Calculate the mechanical advantage of a seesaw that allows a 40 kg person to lift a 60 kg person.
   (b) Draw a scaled diagram to show how these two people can balance a 6 m long seesaw.
3. Explain how the distance between the fulcrum and the effort affects the mechanical advantage of a lever.

CREATE

4. Draw or design a piece of playground equipment that makes use of at least one lever. Be sure to label the fulcrum, load and effort.

CONNECT

5. Go to www.jaconline.com.au/science/weblinks and click on the Balancing Frogs link for this textbook to balance some frogs on a seesaw.

✓ checklist

I can:
- ☐ understand what occurs if the fulcrum is moved
- ☐ relate the mechanical advantage of a lever to the distances between the effort, fulcrum and load.

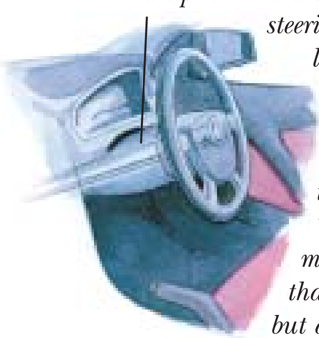
checkpoint

On the road

Imagine what it would have been like to travel long distances without cars, motorbikes and bicycles. A few hundred years ago you would not have been able to use any of those wheeled vehicles. In fact, the **wheel** itself was not invented until about 3500 BC. How different would our lives be without wheels?

Levers in a spin

Wheels are levers that rotate around the fulcrum. They are attached to a smaller wheel called an **axle**. The wheel and the axle turn in circles around the **fulcrum**, but the wheel moves through a larger circle than the axle. Like other **levers**, a wheel and axle can be used as a **force multiplier** or a **speed multiplier**. A wheel and axle act as a force multiplier when the **effort** is applied to the big wheel. If the effort is used to move the small axle, the machine acts as a speed multiplier.



This wheel and axle acts as a force multiplier. The driver can turn the steering wheel with very little effort. The outer edge of the steering wheel turns through a bigger distance than the steering column. The steering column moves a smaller distance than the steering wheel, but applies a much greater ***force*** *on the heavy tyres of the car.*

This wheel and axle acts as a speed multiplier. A big force from the engine moves the axle a short distance. The wheel turns in a much larger circle than the axle. The outside edge of the wheel spins very quickly compared to the axle.

Compound machines

Cars and bicycles are **compound machines**. They are made up of many simple machines working together. As well as the wheels and axles that move them along, they have levers like handlebars, handbrakes and brake pedals. A special kind of wheel, called a **gear**, is another simple machine found in cars and bikes.

Handbrake

This handbrake is a ***first-class lever****. When the rider squeezes the handbrake, their effort is transferred along the cable to the brake pads that press against the wheel.*

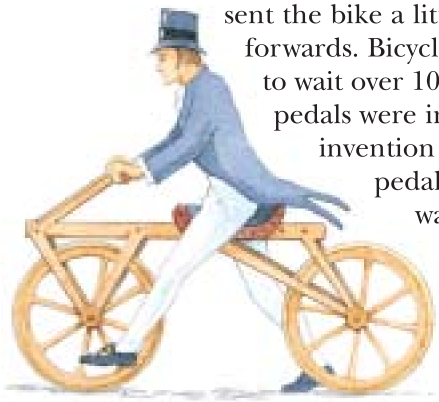
Bike chain

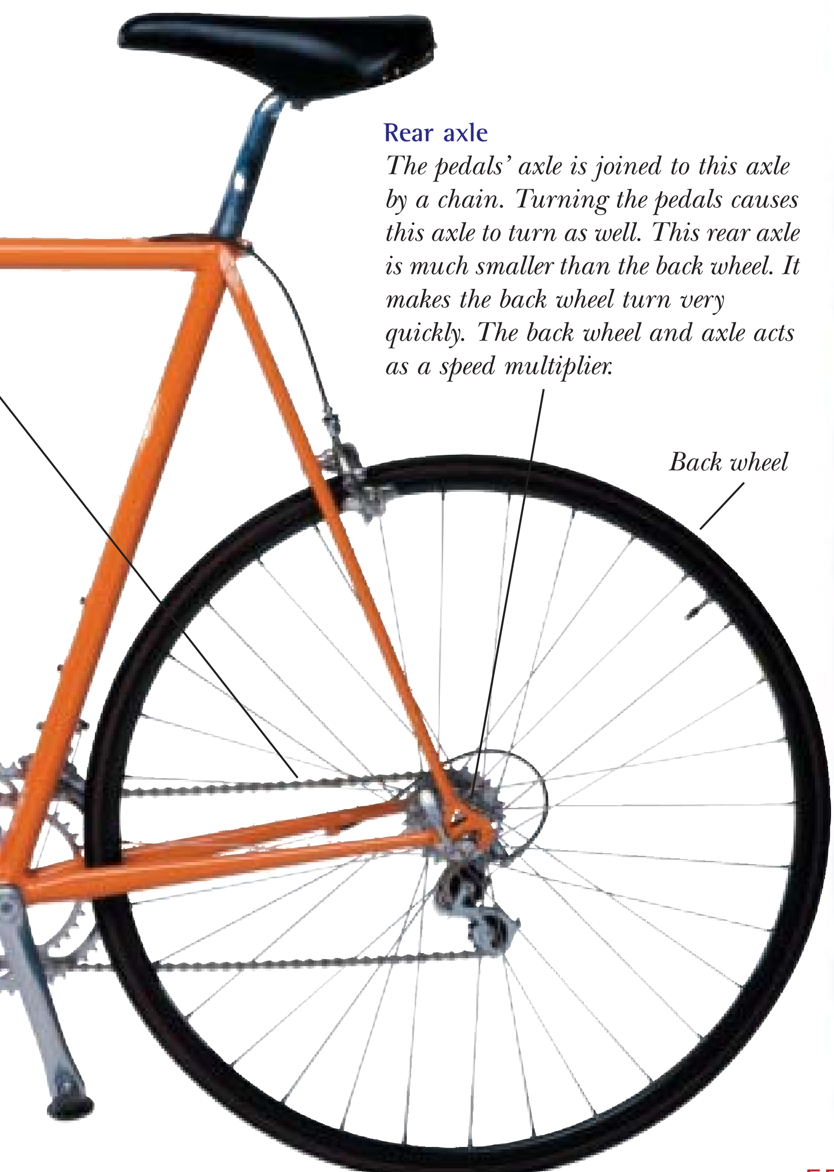
It is possible to join wheels or axles together with chains or belts. Bikes have chains rather than belts because they are less likely to slip off. The pedals' axle and the rear axle have teeth that mesh together with the chain. Wheels with teeth on them are called gears.

Pedals

The pedals turn in a larger circle than the axle they are attached to. The axle can move a bigger ***load*** *than the pedals. This part of the bike is acting as a force multiplier.*

One of the first bicycles invented was called the 'swiftwalker'. It didn't have pedals. The 'walker' had to push off the ground to make the bike go forwards. Both feet were then lifted off the ground and the bike coasted forwards. Another push sent the bike a little further forwards. Bicycle walkers had to wait over 100 years before pedals were invented. The invention of the pedal turned walkers into 'riders', but, without rubber tyres, it was a very bumpy ride!





Activities

REMEMBER

1. Which part of a wheel is like the fulcrum of a lever?
2. Explain the difference between compound and simple machines.

THINK

3. Complete these sentences:
   (a) When a big wheel is used to turn a small wheel, the ______________ is multiplied.
   (b) When a small wheel turns a bigger wheel, the ______________ is multiplied.

COMPARE

4. (a) How does the size of a steering wheel in a bus compare with the size of a steering wheel in a racing car?
   (b) Suggest a reason for the difference in size.

CREATE

5. Make a **belt drive** using Lego® or another building kit. Use appropriate wheels to make:
   (a) a force-multiplying belt drive
   (b) a speed-multiplying belt drive
   (c) a belt drive that does not multiply speed or force.

CONNECT

6. Find out who invented the rubber tyres that are used on bicycles. Also find out when rubber tyres were first used.

checklist

I can:
- ☐ describe a compound machine as a device made up of many simple machines
- ☐ distinguish between speed-multiplying and force-multiplying wheels and axles.

On the road again

The **gears** on a bike usually act as **speed multipliers**. Depending on the type of bike you own, they can make a hill a little easier too. The gears on a bike are called **sprockets**. A chain links the sprockets around the pedal with those on the back wheel. In most cases, the front sprockets of a bike are bigger than the back ones.

Getting into gears

The gear that moves first is called a **driving gear**. The front sprocket of a bike is a driving gear. The front sprocket makes the rear sprocket turn. The rear sprocket is a **driven gear**.

When a large driving gear turns a small driven gear, the small gear turns faster. These gears are speed multipliers. Most bicycle gears are speed multipliers because the front driving sprockets are usually larger than the rear driven sprockets.

What if you are going up a hill? You would need your bike to act more like a **force multiplier** than a speed multiplier. Some bikes have several sprockets. Choosing a different combination of gears makes hills easier to tackle.

Bike gears

When a small gear drives a big gear, the big gear turns with less speed, but greater **force**. This combination of gears is a force multiplier. But not many bikes allow you to choose a front sprocket that is smaller than the rear sprocket.

The best combination for going up hills is when the smallest front sprocket is used with the biggest rear sprocket. The pedals need to be turned more, but the reward is an easier uphill ride. This combination of gears is called low gear.

Along a flat road, high gears are used to move a bike quickly. The largest front sprockets are linked to the smallest rear sprockets. In high gear, you have to push harder, but the reward is that you don't have to pedal as fast.

Notice that the smallest front sprocket is used with the biggest rear sprocket. This combination of gears makes it easier to go up hills.

The combination of a large front sprocket and a small rear sprocket makes the bike go faster.

Machine on a lean

The gears in a car can be used as force multipliers to help a car make it up a steep incline. But the shape of a road can help too. Steep hills and mountains have roads that wind around them. Winding roads make the trip much easier, but the distance to the top is much greater than if the road climbed straight up the hill. A winding road is a simple machine called an **inclined plane**. Inclined planes reduce the effort needed to raise objects to a higher level.

Getting going again

A car jack is an inclined plane. The winding 'road' on the jack forms a **thread**. The closer the turns of the thread, the more the jack magnifies your **effort**. The threaded part of the jack is a special inclined plane, called a **screw**. The screw brings the sides of the jack closer together when the jack handle is turned. As the sides move in, the top of the jack lifts the load.

Go to worksheet 12

Go to worksheet 13

Activities

REMEMBER

1. What is a sprocket?
2. Complete these sentences:
   When a bigger gear turns a smaller gear, the driven gear turns with increased ______________.
   When a smaller gear turns a larger one, the driven gear turns with increased ______________.
3. When would you most likely ride a bike in low gear?
4. Apart from changing the speed and force of turning, what else can gears do?

THINK

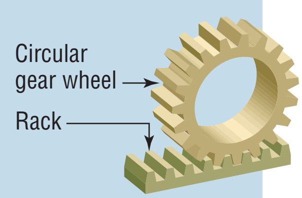
5. Answer the following questions about the four different gear combinations listed.
   A A bike whose chain links a front sprocket of 56 teeth with a rear sprocket of 24 teeth
   B A bike whose chain links a front sprocket of 40 teeth with a rear sprocket of 24 teeth
   C A bike whose chain links a front sprocket of 40 teeth with a rear sprocket of 32 teeth
   D A bike whose chain links a front sprocket of 56 teeth with a rear sprocket of 32 teeth
   (a) Explain which of the combinations above would be best for uphill riding.
   (b) Explain which of the combinations above would be best for riding along a flat road.

CREATE

6. Use Lego® or any other building kit to set up two gears that mesh together. Starting with a gear with 16 teeth and a gear with 8 teeth, investigate the number of turns the driven gear makes for one turn of the driving gear. Investigate gears with different numbers of teeth.

INVESTIGATE

7. Find out what **rack and pinion gears** are and how they work in a car.
8. Find out what an **idler gear** is used for.



checklist

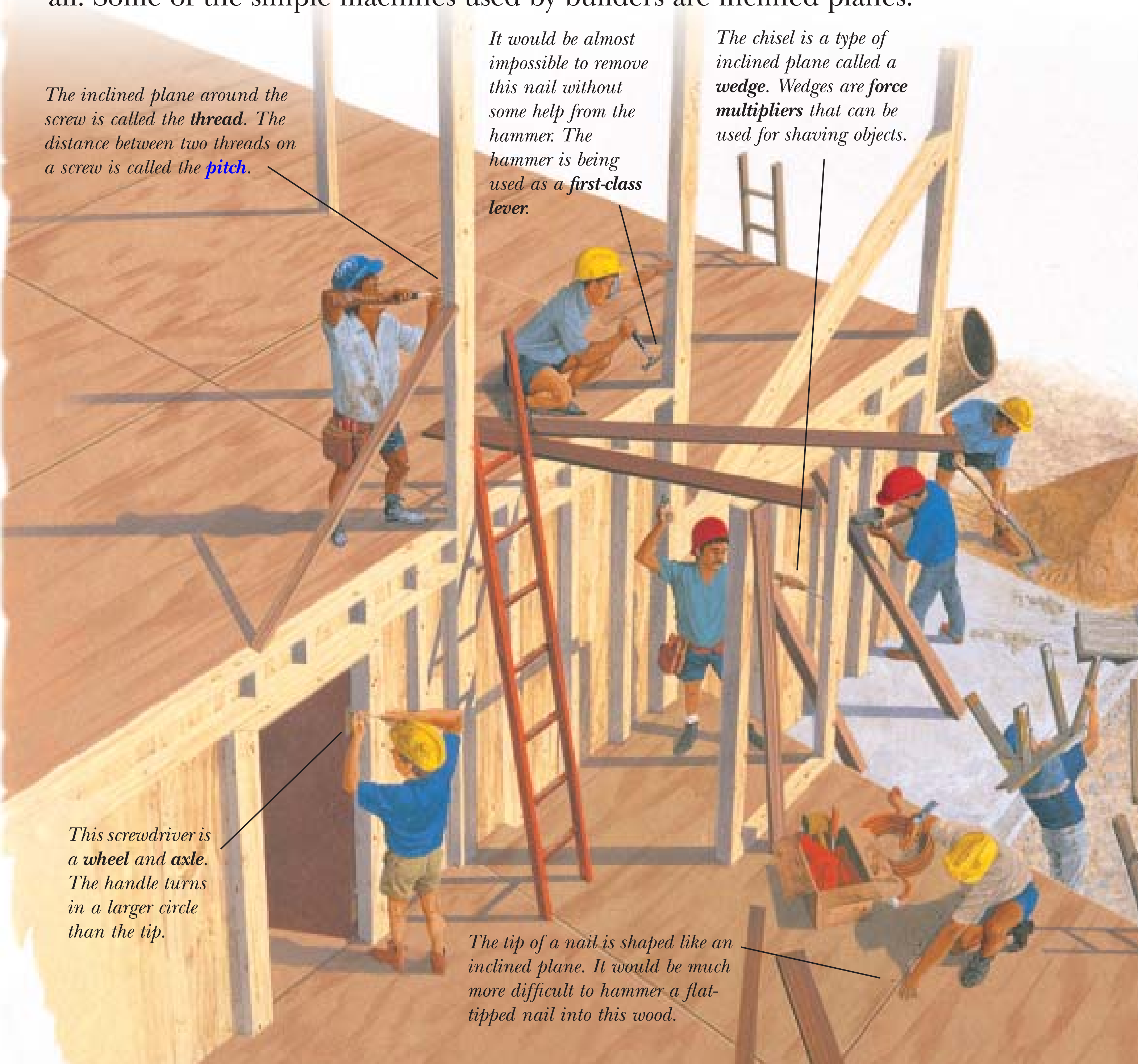
I can:

- ☐ combine gears to form speed multipliers and force multipliers
- ☐ use an inclined plane as a force multiplier
- ☐ recognise different types of inclined planes.

On the building site

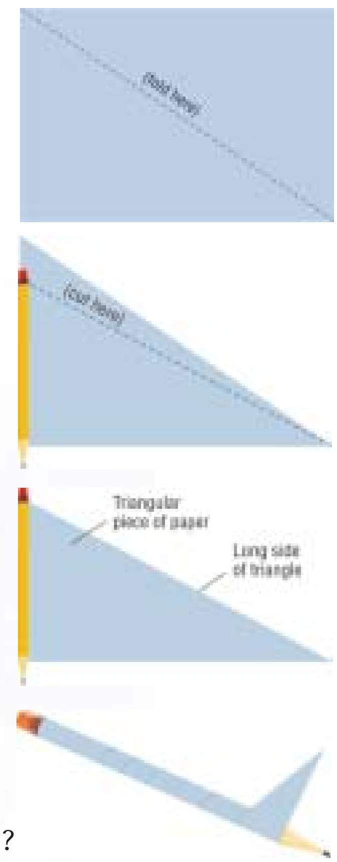
Inclined planes can be as big as a road winding around a mountain. They can also be as small as the tip of a nail. They can split objects apart or hold them together. Many inclined planes are found on building sites.

It takes months to build a house: cutting timber frames to size, nailing the frame together and carting bricks. Many simple machines are used by builders and construction workers to make their jobs easier. Without these simple machines a house would take much longer to build, and some tasks could never be done at all. Some of the simple machines used by builders are inclined planes.



The length of a screw thread

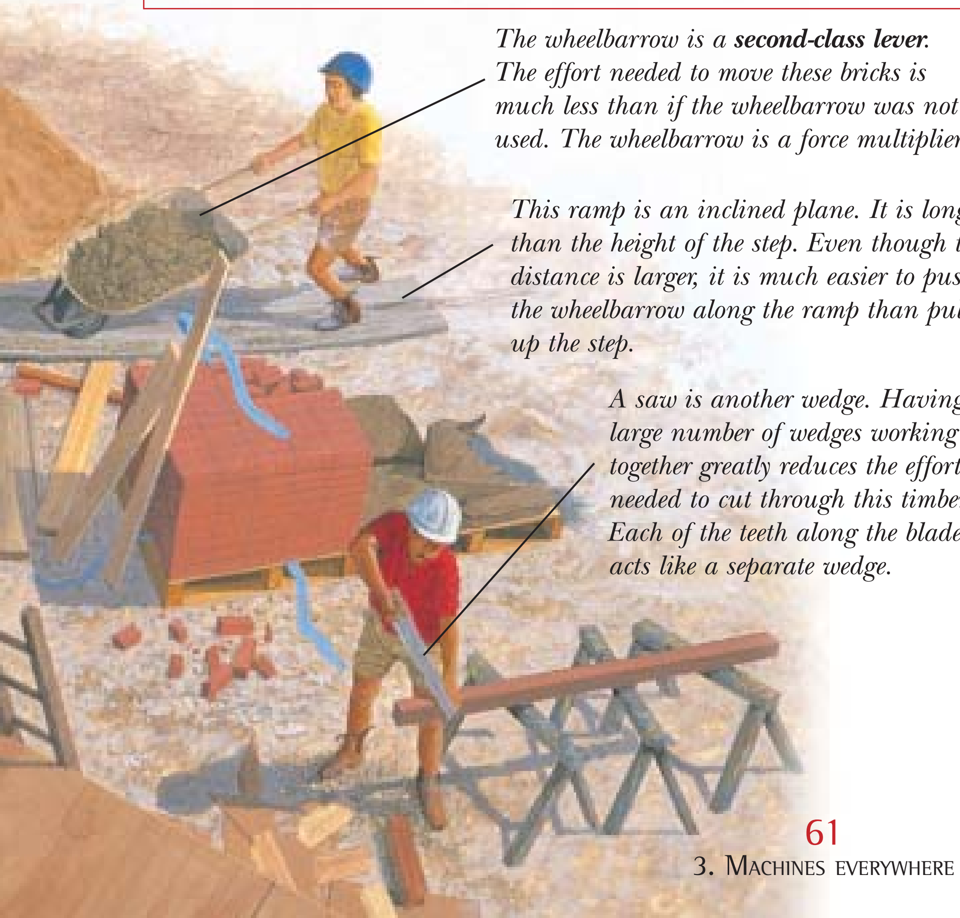
A screw is a curved inclined plane. When a screw is used to hold objects together, it needs to be turned through the length of the thread. The **effort** is applied over a much larger distance than if the screw was driven straight into the objects. The distance a screw actually travels through the timber is longer than the length of the screw.



You will need:
a pencil
A4 piece of paper
scissors.

- Fold the paper in half, diagonally, to make a right-angled triangle.
- Cut along the fold. You will need only one of the triangles.
- Cut the triangle so that its height is less than that of the pencil.
- Measure the height of the triangle.
- Measure the length of the longest side of the triangle.
- Wrap the paper triangle around the pencil.

1. If the pencil were a screw, how deeply could the screw reach into a piece of timber?
2. How far has the screw actually turned?



The wheelbarrow is a ***second-class lever****. The effort needed to move these bricks is much less than if the wheelbarrow was not used. The wheelbarrow is a force multiplier.*

This ramp is an inclined plane. It is longer than the height of the step. Even though the distance is larger, it is much easier to push the wheelbarrow along the ramp than pull it up the step.

A saw is another wedge. Having a large number of wedges working together greatly reduces the effort needed to cut through this timber. Each of the teeth along the blade acts like a separate wedge.

Activities

REMEMBER

1. Make a sketch of a screw, and add labels to show why it is an inclined plane.
2. Give two examples of wedges used on a building site.
3. List an advantage and a disadvantage of using a ramp as an inclined plane.

THINK

4. Imagine two screws that are identical, except for the height of their pitch. What difference would you notice using each of the screws?

FIND

5. List all of the following types of machine that you can find at the building site under the following headings:
   (a) speed multipliers
   (b) first-class levers
   (c) second-class levers
   (d) wheels and axles
   (e) inclined planes.

INVESTIGATE

6. A spring balance can be used to measure forces. Use a spring balance to measure the effort force needed to pull an object up an inclined plane. Compare this with the effort needed to lift the object straight up the height of the inclined plane.

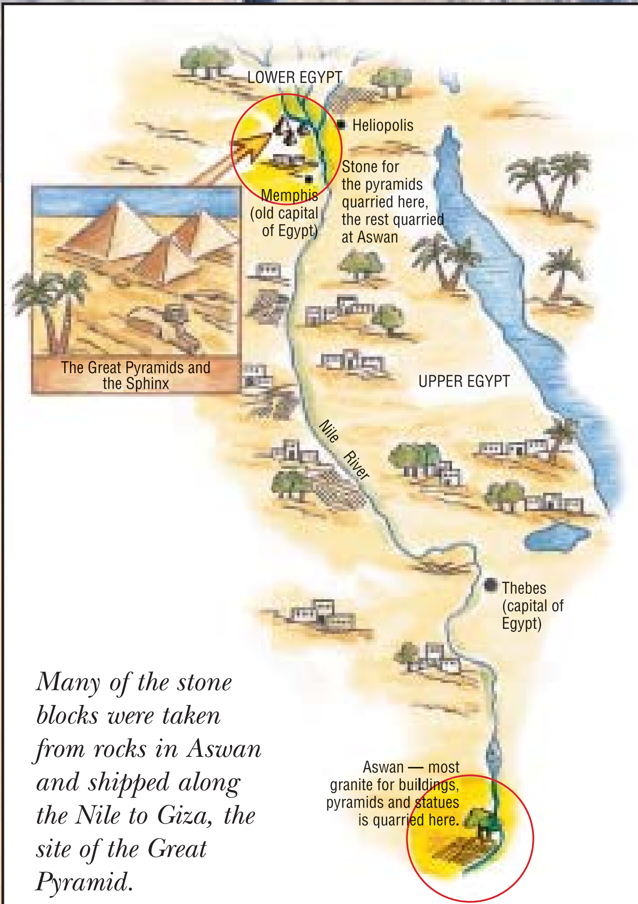
checklist

I can:
- ☐ describe some simple machines used on building sites
- ☐ explain what the pitch of a screw is
- ☐ understand why inclined planes are useful.

PAPYRUS PRESS

27 June 2500 BC | Weather: Hot

THE GREAT PYRAMID IS COMPLETED!



Many of the stone blocks were taken from rocks in Aswan and shipped along the Nile to Giza, the site of the Great Pyramid.

Pharaoh Khufu has rejoiced at the sight of his Great Pyramid! He has publicly praised the 100 000 men who have worked for him for the past 20 years. The pharaoh has promised the workers that the gods will look down on them and guide them.

The Great Pyramid will be an impressive burial place for our great pharaoh. It stands almost 150 metres high and covers 5 hectares of land. About two million stone blocks have been precisely cut and placed to make the pharaoh's tomb. Each stone block weighs about 2 tonnes.

The stonecutters have worked continually for years. They used their chisels and drills to cut the stones to fit together perfectly. In fact, the stones fit together so closely that a knife blade cannot be wedged between them.

The surveyors and engineers have made sure that the base rocks are as flat as possible. There is only about 2 centimetres difference between diagonal corners that are over 300 metres apart.

Our Great Pyramid will stand for many years and tell our children and their children of the brilliant skills of the Egyptians. And it will tell our future generations of the magnificent machines that we have mastered.

Engineering a miracle!

The building project is a credit to all the workers, their skills and their machines. We spoke to Chefre, the head **engineer** working on the Great Pyramid. He explained to us how the Great Pyramid was built.

Papyrus Press (PP): *What great machine was used to place the stone blocks on the water vessels at Aswan?*

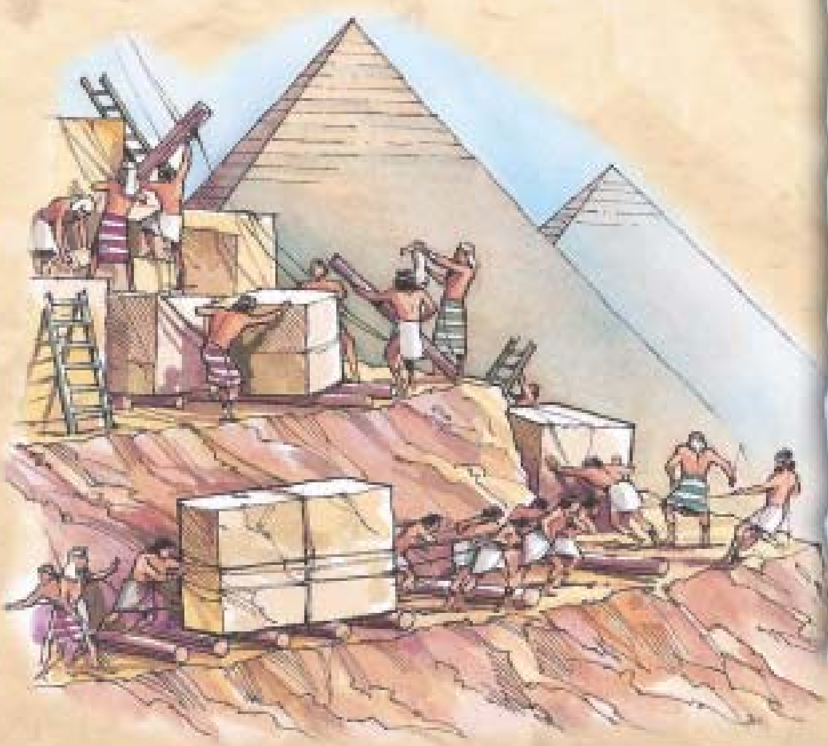
Chefre (C): *The engineering teams have shown the workers how to use **levers** to lift heavy stones. We gave them long levers made of wood and **fulcrums** made of stone. The levers make it possible for five men to do the work of ten! The workers moved the fulcrum and changed the length of the levers to multiply their **effort** as much as possible.*

PP: *What about moving the stones from the river to the building site? Surely they were heavy to drag along?*

C: *Again, a very simple machine made the job much easier. The workers used their levers to lift the heavy stones onto large wooden rollers. The rollers move across hard ground much more easily than dragging the stones without rollers.*

PP: *What sort of magical machine did you use to lift the blocks high up the sides of the pyramid?*

C: *We made long, giant ramps that led up the sides of the pyramid. We used the rollers to haul the stones along the ramps. As the pyramid grew taller, we made the ramps bigger and higher. My assistant suggested wetting the ramps. The water made the ramps slippery, so the rollers moved more easily up the slope.*



Activities

REMEMBER

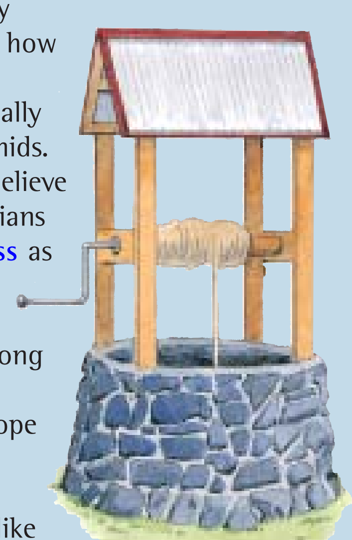
1. How long did it take for the Great Pyramid to be built?
2. How many men are believed to have worked on the construction of the Great Pyramid?
3. What did the ancient Egyptians use levers for?

THINK

4. What type of simple machine was used to move the large stone blocks?
5. What type of simple machine is a ramp?
6. Are the ramps the Egyptians used **speed multipliers** or **force multipliers**? Explain your answer.
7. What simple machines did the stonecutters use?

CREATE

8. Draw a picture to show how ancient Egyptian workers might have used a lever to raise a massive stone onto rollers.
9. There are many theories about how the ancient Egyptians actually built the pyramids. Some people believe that the Egyptians used a **windlass** as well as the rollers to haul large stones along the ramps. A windlass is a rope attached to a pole with a handle, much like a well. The other end of the rope was tied to the stone block. Draw what you believe an Egyptian windlass would look like. Write a short explanation of how it would work.



checklist

I can:

- ☐ describe how simple machines may have been used in the construction of the pyramids in ancient Egypt.

Way back when …

During the 1850s, visitors from all over the world flocked to the Victorian goldfields in search of riches. Many of the visitors brought with them new skills and new machines to help them find their fortunes.

At first the gold was easy to find because it lay in streams of water. Soon almost all of the surface gold was gone. It became necessary to start digging for gold. The technology that we have today was not available, so simple machines were used to dig for the gold, haul it to ground level and separate it from rock.

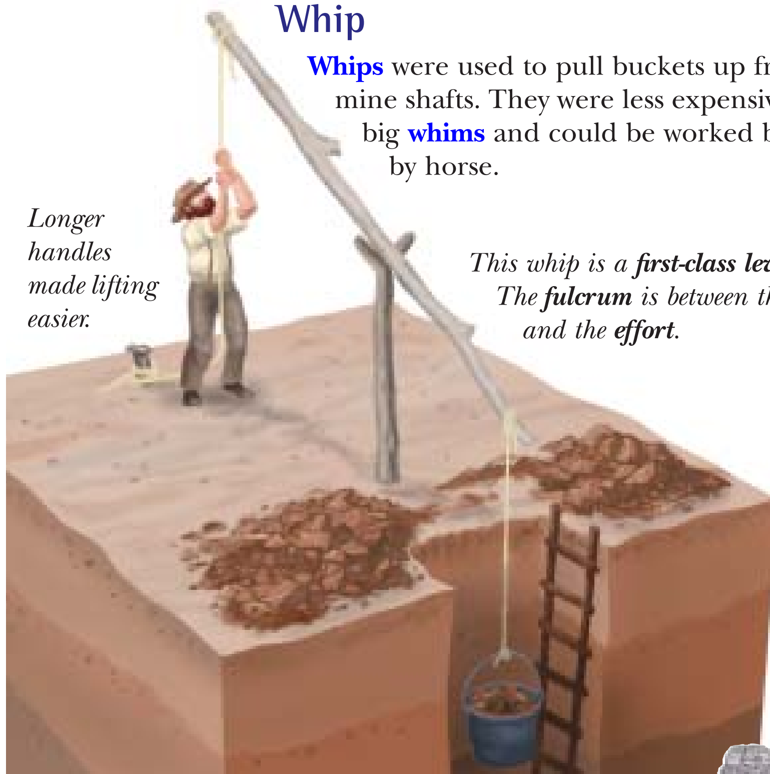
Windlass

Mining shafts were dug to about 40 m deep. The problem of lifting the rocks and soil to the top of the shaft was solved with a wheel and axle called a **windlass**.

The rope is tied to a bucket. The bucket is filled with rocks and soil at the bottom of the mine. When it is full, the miner at the top turns the handle (the wheel). The rope winds around the axle, raising the bucket. After the bucket is emptied at the top of the mine, the windlass is also used to return the bucket to the miners at the bottom of the shaft.

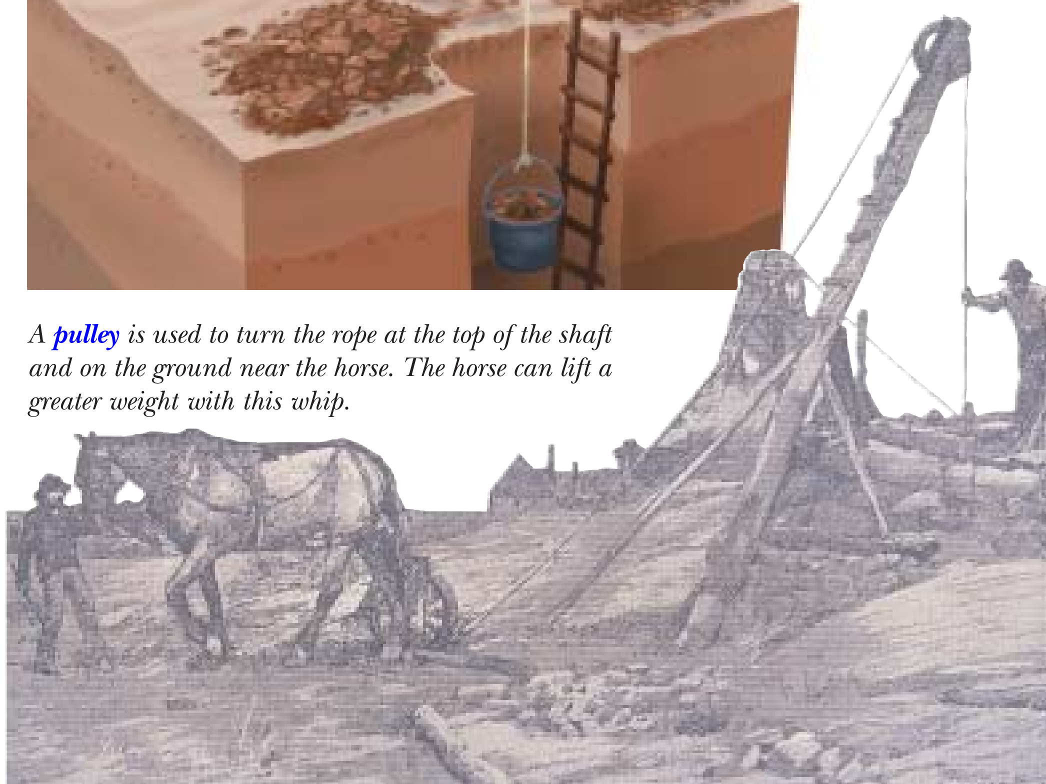
Whip

Whips were used to pull buckets up from deep mine shafts. They were less expensive than the big **whims** and could be worked by hand or by horse.



Longer handles made lifting easier.

*This whip is a **first-class lever**. The **fulcrum** is between the **load** and the **effort**.*

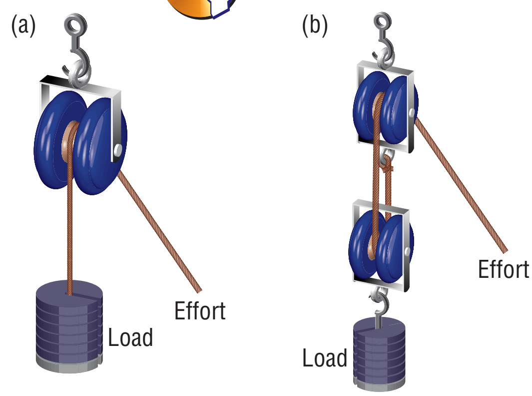


*A **pulley** is used to turn the rope at the top of the shaft and on the ground near the horse. The horse can lift a greater weight with this whip.*

Go to worksheet 14

HOW IT WORKS

A pulley is useful for lifting something upwards by pulling downwards. A block and tackle is made up of many pulleys joined together. Two or more pulleys used together are force multipliers. For each extra pulley, the machine magnifies your effort even more. The only disadvantage of a block and tackle is that the effort needs to be applied over a long distance.



Whim

When most of the gold near the surface had been removed from the shallow mines, the miners had to dig deeper to search for gold. The whim was used to haul two large buckets up very deep shafts.

*The horse walks in a very large circle to make the drum turn. As the drum turns, the rope lifts one bucket and lowers the other. The horse walks in a large circle to turn the drum. The horse's effort is multiplied, so it can move the buckets easily. This machine is a **wheel** and **axle**.*

These grooved wheels turn so that the rope moves smoothly over them. They are called pulleys.

Activities

MI BODILY/KINAESTHETIC

REMEMBER

1. Why are two pulleys better than one?
2. What is a block and tackle?
3. What is a disadvantage of the block and tackle?

THINK

4. A pulley is a type of wheel and axle. Where is the fulcrum of a pulley wheel?
5. How could long-handled shovels be a disadvantage to miners?
6. Describe how the hand-operated whip works.

OBSERVE

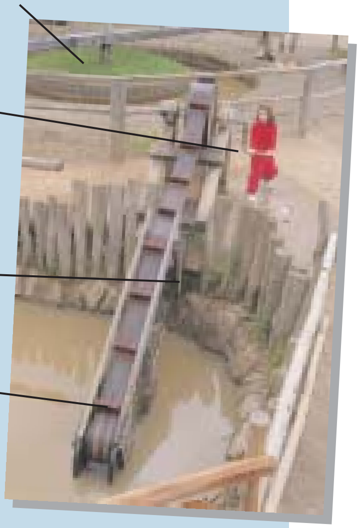
7. A **Californian pump** was often used to pump water from a stream into a **puddling machine**. By looking at the photo, explain how it might work.

Puddling machine

Handle turns conveyor belt

Water travels through chute

Wooden blocks



checklist

I can:

- ☐ explain how pulleys can be used to increase effort
- ☐ describe some uses of simple machines on the goldfields.

Life on the goldfields

The Victorian gold rush started in the early 1850s and lasted about ten years. When 'diggers' first arrived, they had tents and clothes and a few simple tools. As time passed, more and more people, including women and children, moved to the goldfields. With the increasing population came the need for more industries and machines in the goldfield areas.

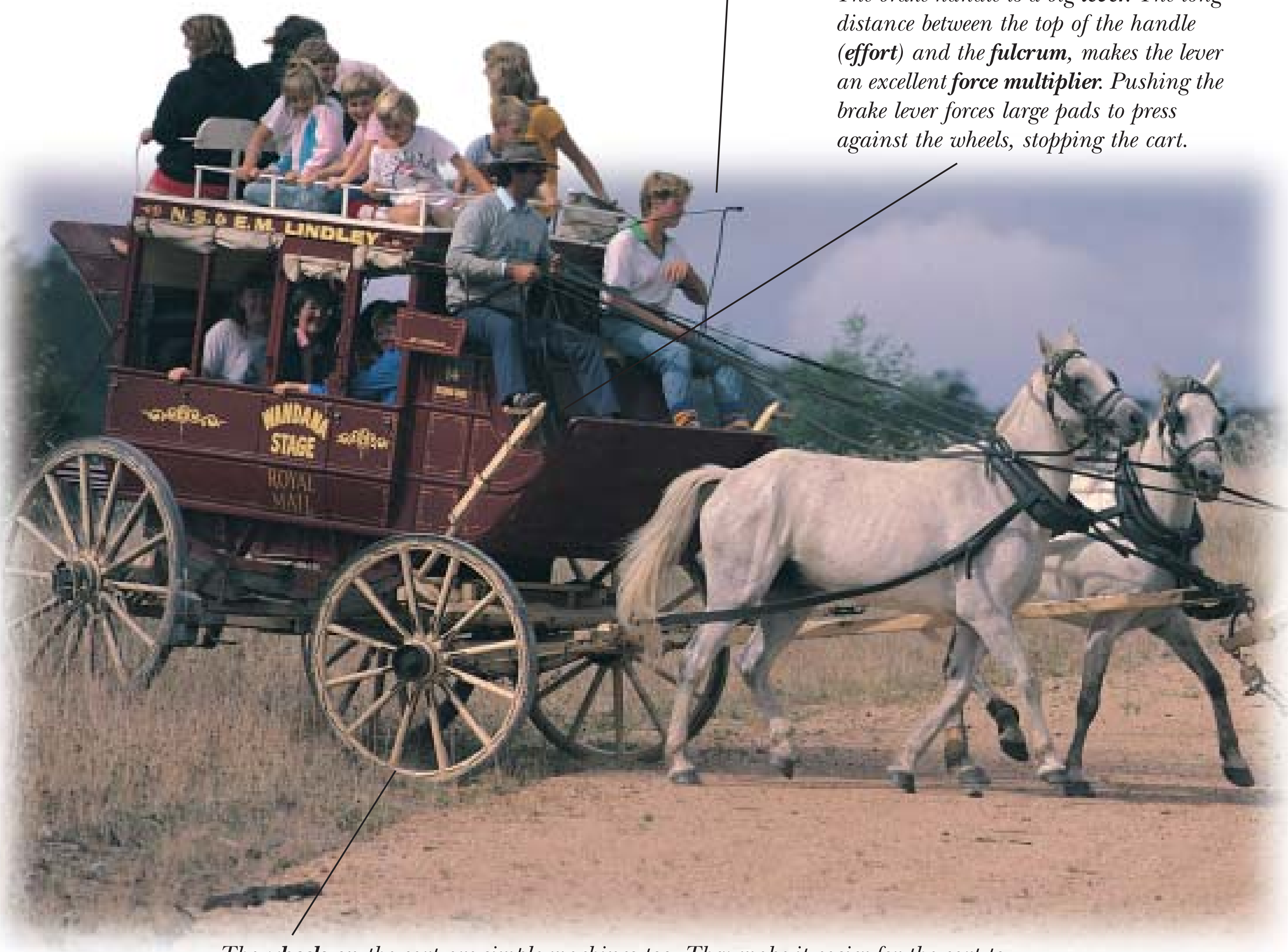
Travel across the goldfields

Horses were one of the main methods of transport on the goldfields. A horse and cart could be used to transport a single person or a group of people, much like a car does today.

The cart itself is a **compound machine**; it is made up of more than one simple machine.

*Horse and cart drivers sometimes carried whips. Whips are **third-class levers**. A quick, short flick of the whip makes the tip of the whip move a big distance, very quickly. Like all third-class levers, the whip is a **speed multiplier**.*

*The brake handle is a big **lever**. The long distance between the top of the handle (**effort**) and the **fulcrum**, makes the lever an excellent **force multiplier**. Pushing the brake lever forces large pads to press against the wheels, stopping the cart.*



*The **wheels** on the cart are simple machines too. They make it easier for the cart to move. Without turning wheels, the cart would drag or slide across the ground.*

Doctor or blacksmith?

Tooth decay was common on the goldfields because of poor diet and dental hygiene. The decay was so bad that teeth began to rot away. The doctor was usually responsible for pulling out rotten teeth. But if the doctor wasn't about, the blacksmith had the tools! The blacksmith's pliers, used for pulling out the nails in horseshoes, were often given a quick rinse and used as doctor's tools.

Pliers were used as levers. The long handles magnified the doctor's (or blacksmith's) effort for a better grip on the teeth.

The candleworks

There was no such thing as electricity on the goldfields. Kerosene lamps and candles provided light once the sun had set. Candles were made with the help of a simple machine at the candleworks known as the **nodding donkey**.

This 'nodding donkey' is a ***second-class lever****. The candle maker pulls down on the handle to dip the wicks into the hot wax. After seven seconds, the wicks are removed from the wax and left to cool. The process is repeated until the candles are of the correct thickness.*

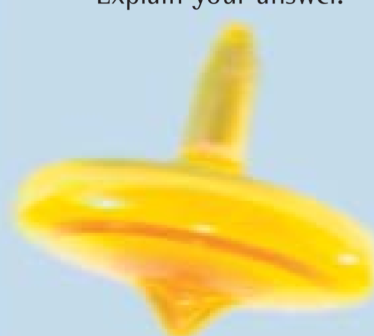
Activities

IMAGINE

1. Life was very different in the 1850s. Imagine you lived in a goldfields township. How would your life differ from your life today? What would you have to go without?

THINK

2. Why does the brake on a horse-drawn cart need to be a force multiplier?
3. Draw a diagram of the whip that the horse and cart drivers used. Label the effort, fulcrum and **load**.
4. What class of lever are the doctor's pliers?
5. Is the nodding donkey a force or a speed multiplier? Explain your answer.
6. Spinning tops were popular toys on the goldfields and are still popular today. These toys are an example of a wheel and axle.
   (a) Draw a sketch of the spinning top and label the wheel and **axle**.
   (b) To which part of the spinning top do you need to apply the effort to make it spin quickly — the wheel or the axle? Explain your answer.



checklist

I can:

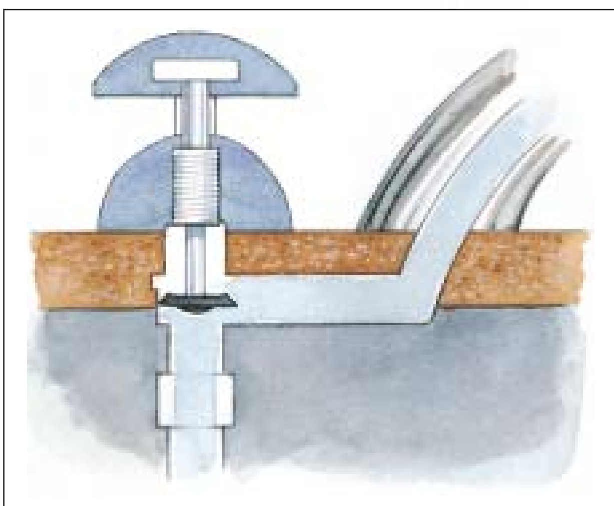
- ☐ explain how some simple and compound machines work
- ☐ describe some uses of simple and compound machines on the goldfields.

Machines in the kitchen

Even some everyday items in the kitchen are simple machines. Without them, we'd find certain tasks almost impossible — like slicing a piece of meat, prising the lid off a coffee tin or stopping the flow of water into the sink. Kitchen machines can be used to multiply our effort. Tap handles and can openers are examples of **force multipliers** in our homes. Other machines, like eggbeaters, speed up our **effort**. Eggbeaters also change the direction of our effort.

*A ceiling fan is a speed-multiplying **wheel** and **axle**. Electricity is used to apply a huge effort to the small axle in the fan's shaft. The fast-spinning blades form the wheel of the simple machine.*

*The blade of a knife is a sharp **wedge**. It makes chopping much easier and so does the long handle. The handle acts as a **lever**. Longer handles are needed to cut through harder foods.*

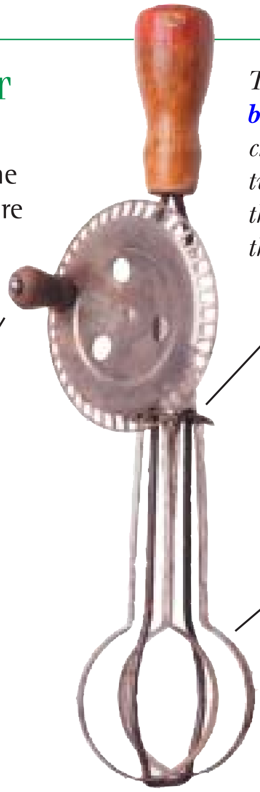


Taps are wheels and axles. Larger tap handles are easier to turn than smaller ones. When the handle is turned, the axle turns, moving a small washer inside the tap to let the water flow through it.

*Try closing a door by pushing it close to the hinge. It is much harder than closing the same door from the handle. The door is a **second-class lever**.*

The eggbeater

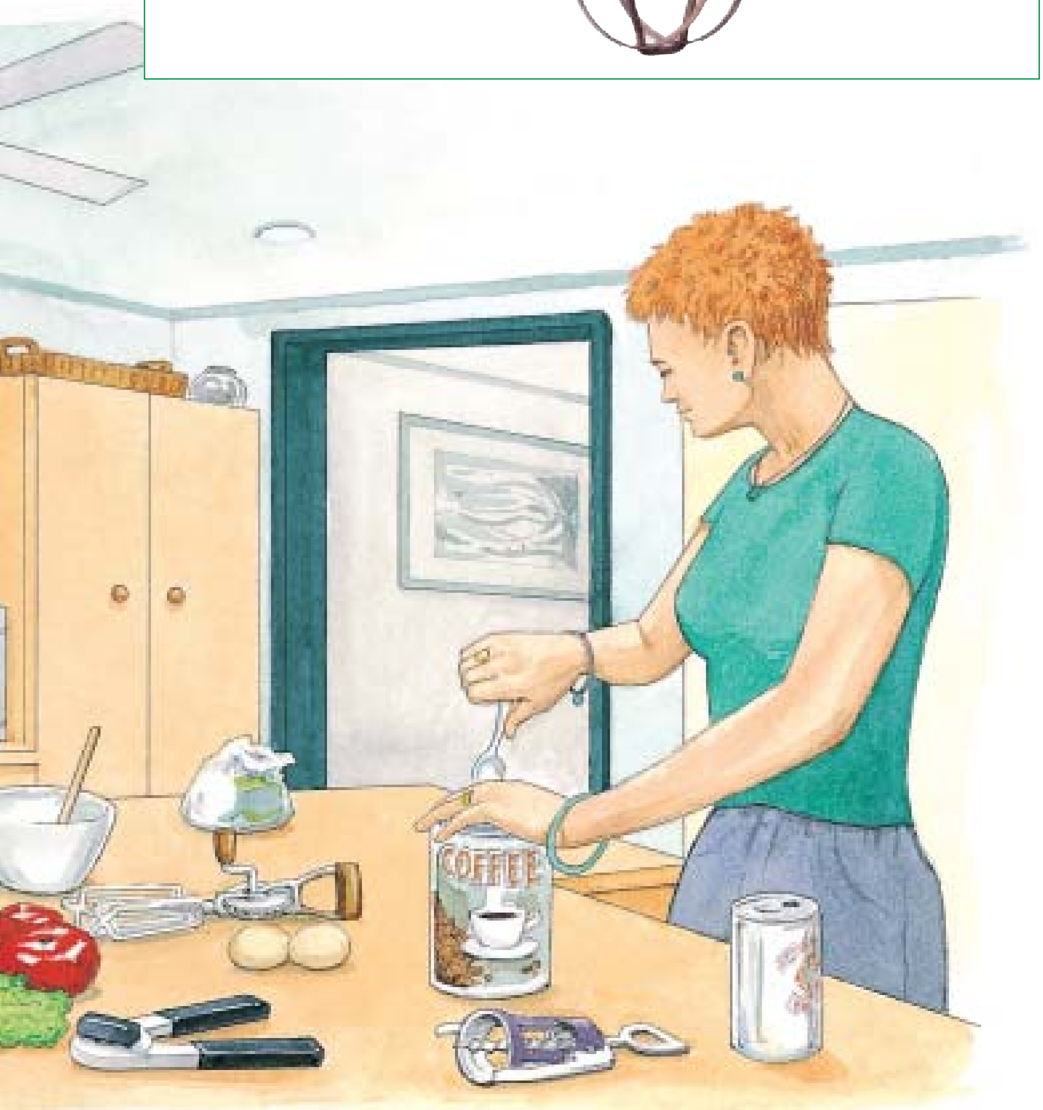
Eggbeaters are **compound machines.** The gears used in eggbeaters are designed to change the direction of the effort. They also act as **speed multipliers,** making it easy to turn the beaters quickly.



*These gears are **bevelled gears**. They change the vertical turn of the handle into the horizontal spin of the beaters.*

This handle turns in a big circle. It makes the smaller bevelled gears turn with greater speed.

The beaters spin much faster than the handle turns.



Go to worksheet 15

Activities

SEARCH

1. Look carefully at the kitchen scene on this page. List the objects that work as simple machines. For each object, describe the simple machine and how the machine creates an advantage.

REMEMBER

2. Why are bigger tap handles easier to turn than smaller ones?
3. Label the effort, **fulcrum** and **load** on the cupboard door.
4. What class of lever is the knife when you are chopping?
5. What are bevelled gears?

THINK

6. The tap uses more than one simple machine. By looking at the diagram, find one other simple machine inside the tap. Describe how it works as a simple machine.

OBSERVE

7. Take a close look at this corkscrew. List at least three simple machines that work together in a corkscrew. Explain how they work together.

checklist

I can:
- ☐ describe how bevelled gears work
- ☐ explain how some simple machines work together in compound machines.

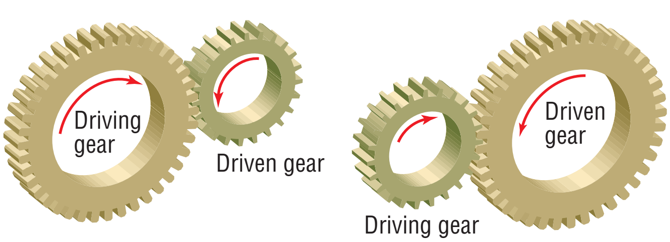
Check and challenge

Machines everywhere

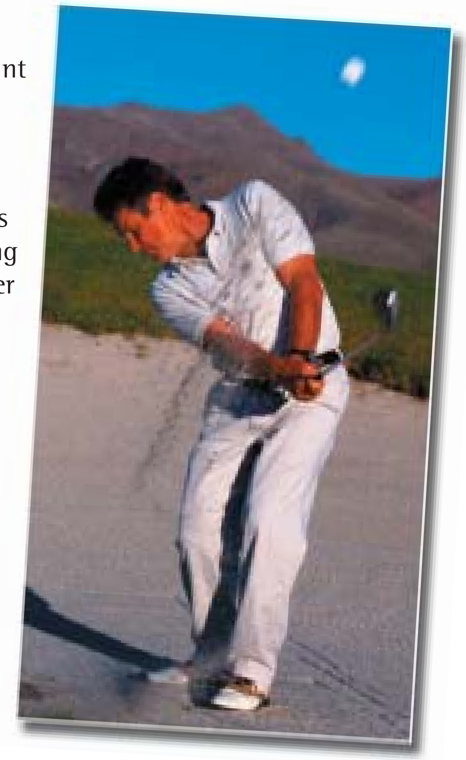
Changing force and speed

1. List two classes of levers that magnify effort.
2. Softballers use a softball bat to hit the ball a long distance at very high speeds.
   (a) Sketch the softballer and her bat. Label the effort, fulcrum and load on your diagram.
   (b) What class of lever is the softball bat?
   (c) Is the softball bat acting as a speed or force multiplier?

3. Which of the following is a speed multiplier and which is a force multiplier?



4. Draw a diagram to show how a pulley can be used to change the direction of a force.
5. Which of the following machines can act as speed multipliers:
   (a) a single pulley?
   (b) wedge?
   (c) first-class lever?
   (d) third-class lever?
   (e) inclined plane?
6. Why is it important for this golfer to use his club as a third-class lever?
7. In golf, a driver is used to make long shots and a putter for making short shots. Why are drivers usually longer than putters?



Mechanical systems

8. Describe what sprockets are and where they can be found.
9. What is a compound machine?
   A A machine that squeezes objects to make them smaller
   B A machine that multiplies your force
   C A machine that multiplies your speed
   D A machine made up of two or more simple machines
10. How is a block and tackle different from a single pulley?

Everyday machines

11. (a) What simple machines are stairs most similar to?
    (b) Do they act as force or speed multipliers?
12. Name and describe the simple machines that are needed to turn a door handle and push open a door.
13. Why aren't door handles in the *middle* of doors?

Mechanical advantage

14. (a) Suggest a way to increase the mechanical advantage of this lever.
    (b) Suggest a different way of using the plank to help load the box onto the truck.

15. Explain why the roads around hills and mountains are winding roads rather than straight roads.
16. A first-class lever is used to lift 12 coins.
    (a) What is the mechanical advantage of the lever when it uses four coins to lift the 12 coins?
    (b) If the 12 coins are placed six centimetres from the fulcrum, how far should the four coins be from the fulcrum to lift the heavier pile of coins?

Getting into gear

17. (a) How is a rack and pinion gear *similar* to a bevelled gear?
    (b) How is a rack and pinion gear *different* from a bevelled gear?

Machines of all types

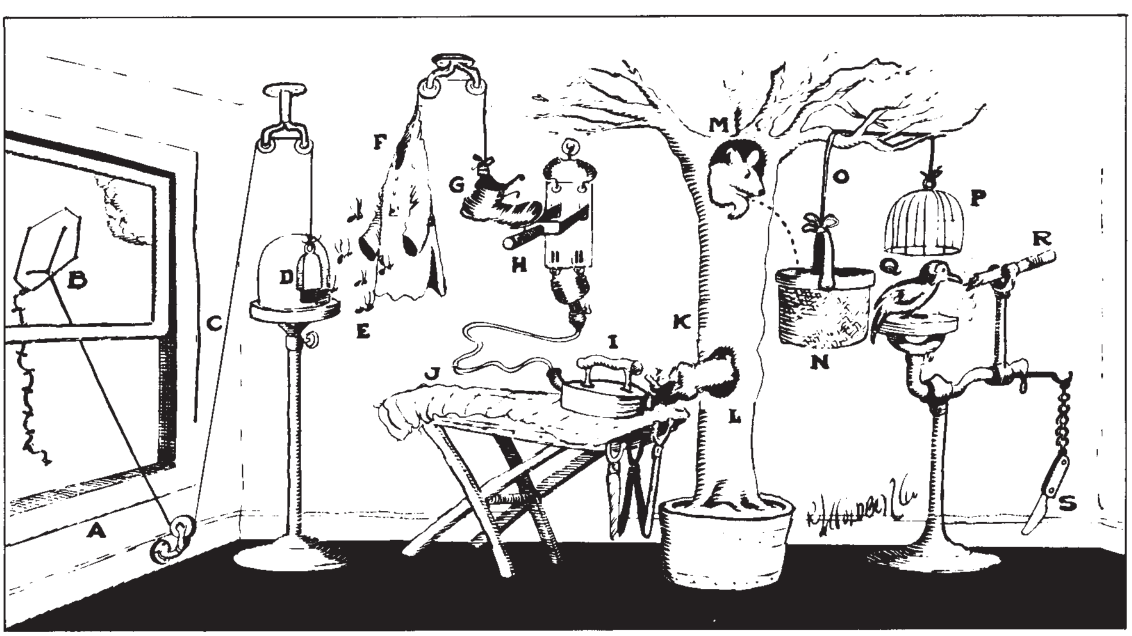
1. Would a lever work without a fulcrum? Explain your answer.
2. Imagine that you wanted to drive a screw into a piece of wood. You have the choice of using a screwdriver with a large handle or one with a smaller handle. Which would you use? Explain your choice.

Magnificent machines

3. Your task is to design a machine that will take five seconds to burst a balloon. Follow these steps to design your machine:
   (a) Look at the cartoon by Rube Goldberg (below).
   (b) In a group of three or four, brainstorm some ideas for simple machines that could be used to construct the balloon-bursting machine.
   (c) As a group, draw a rough copy of a design for the balloon-bursting machine.
   (d) As a group, present a poster of your machine and a brief description of how it works.

How machines work

4. Design a multimedia presentation that outlines how one of the following machines works. Make sure you discuss whether the simple machines used are speed or force multipliers.
   (a) corkscrew
   (b) eggbeater
   (c) car steering system
   (d) bicycle gears
   (e) water tap



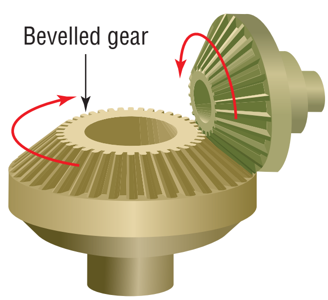
Open window (A) and fly kite (B). String (C) lifts small door (D) allowing moths (E) to escape and eat red flannel shirt (F). As weight of shirt becomes less, shoe (G) steps on switch (H) which heats electric iron (I) and burns hole in pants (J). Smoke (K) enters hole in tree (L), smoking out opossum (M) which jumps into basket (N), pulling rope (O) and lifting cage (P), allowing woodpecker (Q) to chew wood from pencil (R), exposing lead. Emergency knife (S) is always handy in case opossum or the woodpecker gets sick and can't work.

Summary of key terms

axle: a small wheel at the centre of a larger wheel. The axle turns with the larger wheel.

belt drive: a belt drive is much like a sprocket. The difference is that the wheels in a belt drive don't have teeth whereas the wheels in sprockets do.

bevelled gear: a gear that changes the direction of the effort by 90°



Californian pump: a hand-operated compound machine used to collect water from a creek or stream. The Californian pump was widely used on the goldfields to pump water into a puddling machine.

compound machine: a machine made up of more than one simple machine

driven gear: a gear that is moved by another gear

driving gear: a gear that causes another to move

effort: the push or pull used to try to make an object move

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

first-class lever: a lever with the fulcrum between the effort and the load

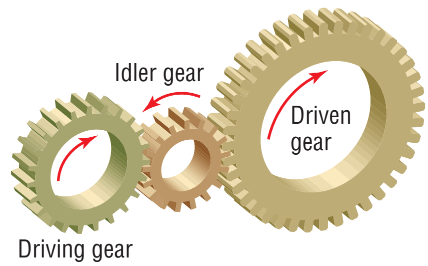
force: a push, pull or twist

force multiplier: a simple machine that multiplies the effort you use

fulcrum: the point around which a lever turns

gear: a toothed wheel that can turn other toothed wheels

idler gear: a third gear added between a driving and driven gear to keep them moving in the same direction



inclined plane: a simple machine that reduces the effort required to raise objects to a higher level

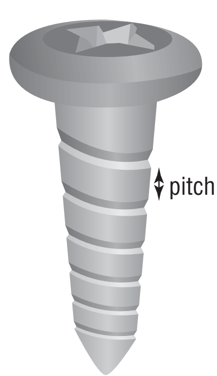
lever: a long, rigid object that moves around a turning point called a fulcrum

load: an object or force that resists motion

mechanical advantage: a measure of how much easier a simple machine makes a task

nodding donkey: a hand-operated compound machine used in the 1800s to dip candle wicks into hot wax during the candle-making process

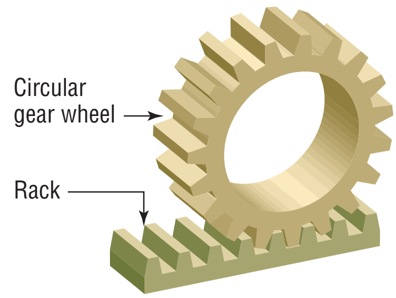
pitch: the vertical distance between the adjacent parts of the thread of a screw



puddling machine: a horse-driven compound machine from the goldfields used to break up rocks and clay. Diggings from mines were placed in this machine with water. Wooden rakes were dragged through the machine to break up the clay so that gold could sink to the bottom of the puddling machine. The muddy water was then drained away so that the gold could be removed.

pulley: a simple machine consisting of a grooved wheel over which a rope can move freely

rack and pinion gears: gears that change circular motion into straight line motion



screw: a curved, inclined plane

second-class lever: a lever with the load between the effort and the fulcrum

speed multiplier: a simple machine that increases the speed of an object

sprocket: gears joined by a chain, as in a bicycle

third-class lever: a lever with the effort between the load and the fulcrum

thread: the curved ridge of a screw

wedge: an inclined plane that pushes objects apart

wheel: a lever that moves in a complete circle. The fulcrum is at the centre of the wheel.

whim: a large wheel, axle and pulley system used to haul large buckets from very deep mine shafts. A whim is operated by horse power.

whip: a lever or pulley system to lift and lower buckets from deep mine shafts. A whip can be operated by hand or by a horse.

windlass: a wheel and axle used to lift and lower buckets from shallow mine shafts