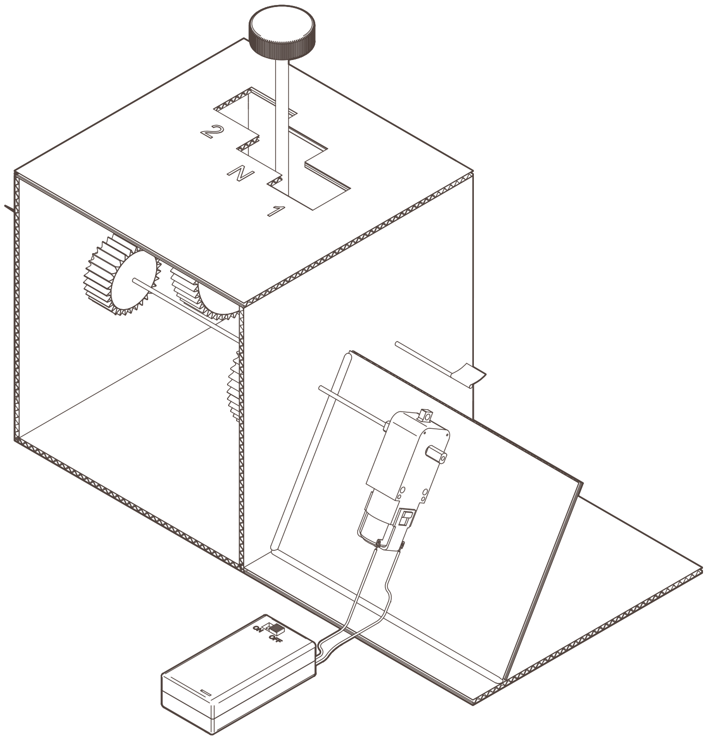


GEARBOX WORKSHEET

GETTING STARTED

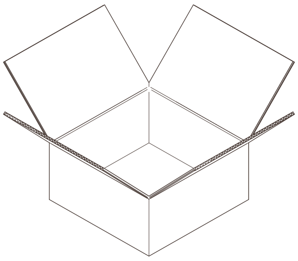
5-10m

Did you know that gears can be found in many of the machines we use every day?

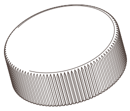
For example, gears allow us to cycle up steep hills on our bicycles, keep time in analogue watches and help the carousel at a fairground turn around.

This activity is suitable for students aged 10+ and will teach you how gears can be used to change speed and show you how to build a model gearbox, just like the one found in a car.

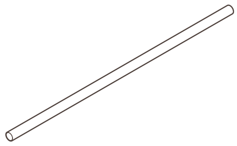
YOU WILL NEED



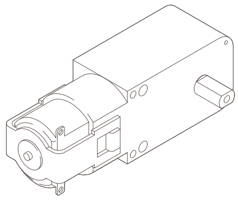
Cardboard box
(min. 45cm in length)
1



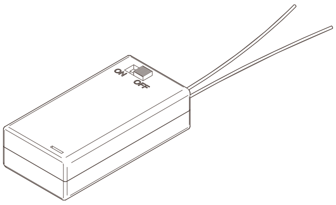
Plastic bottle top
(any size)
1



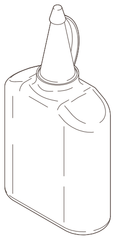
Straws
2



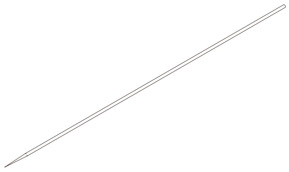
Geared motor
1



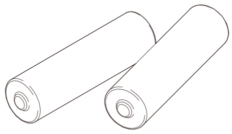
Battery pack with
on-off switch
1



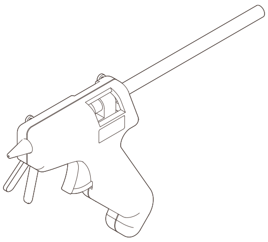
PVA glue
1 TBS



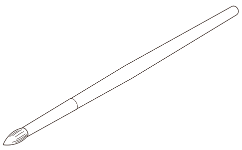
Kebab sticks
3



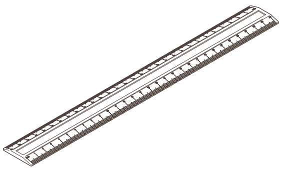
AA batteries
2



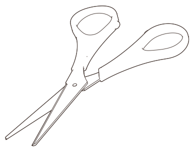
Glue gun
1



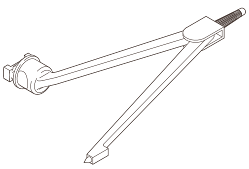
Paintbrush
1



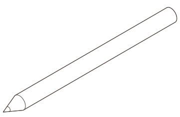
Ruler
1



Scissors
1



Compass
1



Pencil
1

VOCABULARY

Axle - A rod which passes through the centre of a wheel, or a group of wheels.

Diameter - The length of a line that runs from one side of a circle, through the centre, then to the opposite side of the circle.

Gearing Up - A method used to speed up the motion of a driven gear.

Gearing Down - A method used to slow down the motion of a driven gear.

Complete Circuit - A complete loop with electricity flowing from the battery to the components, and back to the battery again.

Shaft - A gear shaft is the axle of the gear, providing the rotation that allows one gear to engage with, and turn, another.

Neutral - The stage in a gearbox when no gear is engaged.

Ratio - Shows the relative sizes of two or more values.

Compass - An instrument with two arms, one sharp and one with a pencil that can be used to draw circles or arcs.

RPM - An acronym for revolutions per minute, measuring rotation frequency.

WARM-UP ACTIVITY

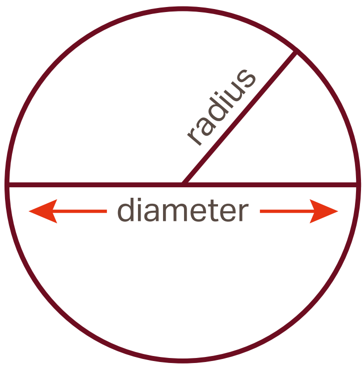
5-10m

For this build, you will need to use a piece of equipment called a compass. If you have not used one before, you might like to take some time to familiarise yourself with this tool.

A compass is an instrument used to draw circles. It consists of two movable arms hinged together, where one arm has a pointed end and the other arm holds a pencil.

To draw a circle:

- Make sure that the hinge at the top of the compass is tightened so that it does not slip.
- Tighten the hold for the pencil so it also does not slip.
- Align the pencil lead with the compass' needle.
- Use a ruler to set the gap between the needle and pencil as the radius of the circle.
- Press down the needle and turn the knob at the top of the compass to draw a circle.



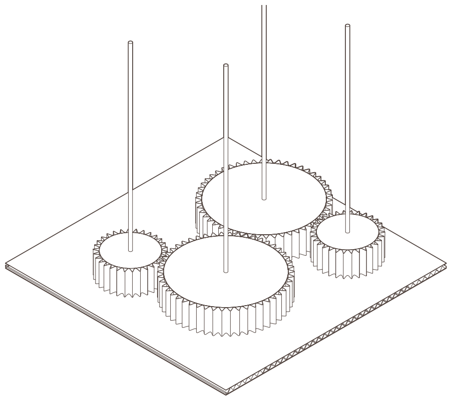
Drawing accurate circles will be important to ensure your gear model runs smoothly. Try constructing circles with a variety of different diameters to develop your drawing skills.

EXTENSION ACTIVITY

10-15m

To work on this task you need to follow the instructions to Step D first.

Before finishing the build and housing your wheels inside the gearbox, investigate how combining gears with different numbers of teeth can change the output speed.



Once the toothed wheels are dry, push some kebab sticks through the holes, to secure the gears in place on a piece of cardboard. Then, use a black permanent marker to make a mark on one tooth on each wheel to help you to see how far it moves when you rotate it.

Consider and investigate the following:

- Using the black marks to keep track, turn the 6cm gear once. How many times does the 3cm gear turn?
- Now, turn the 3cm gear once. How many times does the 6cm gear turn?

Arrange the other gears as you wish and investigate!

MAIN CHALLENGE

1-2 hours

Building a model gearbox is a great way to understand how gears can be used as a simple machine to deliver different speeds and power.

Before you begin construction, make sure you have all the materials and tools that you will need to complete the project.

Wherever possible, try to re-purpose materials that you already have. For example, delivery or shoe boxes are often made of corrugated cardboard.

TOP TIP

Take your time on Step D to ensure a neat join. Gear teeth that do not mesh well together could jam and cause problems later on in the build.

Every time an engineer is faced with a problem, they approach it using the Engineering Design Process:

Ask - What's the problem?

Imagine - Choose a solution.

Plan - Design and choose materials.

Create - Make it.

Test - Test your creation.

Improve - Redesign as needed.

Using this design process, see if you can create a gearbox that runs smoothly. Good luck!

BUILDING THE GEARBOX

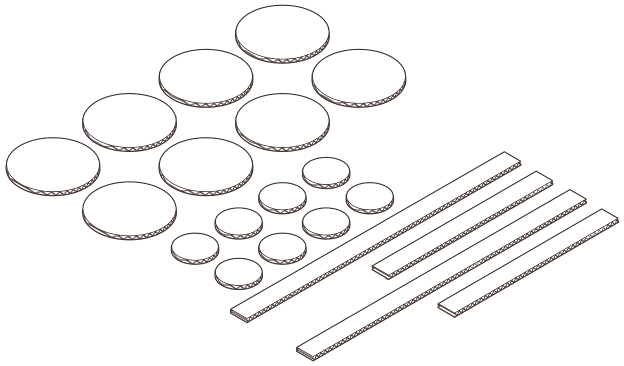
Follow these steps to build your own gearbox model!

A

On a piece of cardboard, use the compass and pencil to draw 8 circles with a diameter of 6cm and 8 circles with a diameter of 3cm.

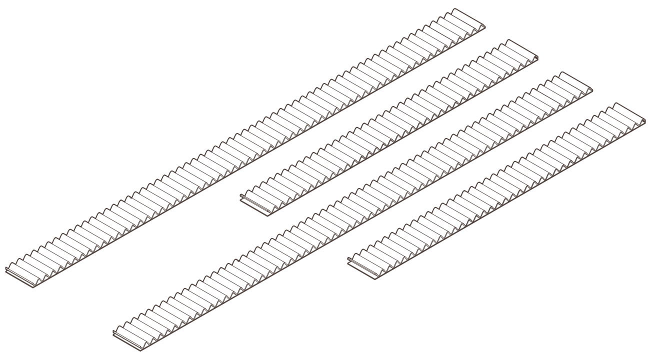
Then, use your ruler to draw two long rectangular strips 25cm by 1.5cm and two shorter 15cm by 1.5cm strips.

Use scissors to cut out all the shapes.



B

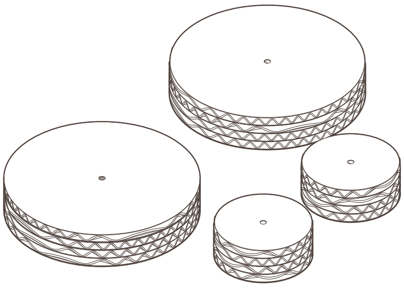
Carefully peel away the top layer of each of the strips so that the ridges of the corrugated cardboard are exposed. These ridges will form the teeth of the gears.



C

Pierce a hole in the middle of each cardboard circle using the kebab stick. You should be able to see the small hole (made by the compass) in the centre of the circle to guide you.

Then, take four of the larger circles and glue them together with hot glue. Repeat with the rest of the circles to make 2 large wheels and 2 small wheels.

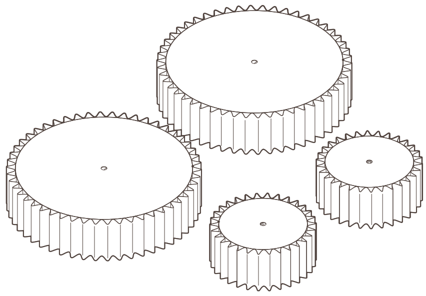


D

Take one of the larger wheels and one of the long strips of card. Trim the strip so it fits around the edge of the wheel. Secure it using hot glue. Take care at this point, to line up the two ends neatly. If they do not meet evenly, the gears will catch when turning. Repeat with the rest of the wheels and cardboard strips.

Next, mix a tablespoon of PVA with a tablespoon of water. Paint the watered-down glue onto the teeth to strengthen them. Leave the wheels to dry.

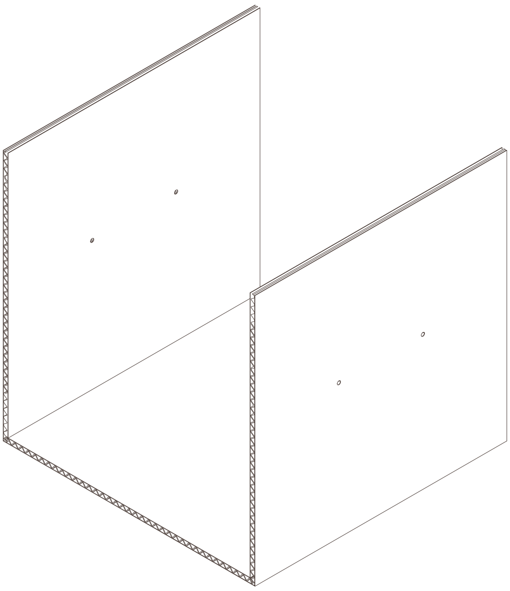
If you would like to investigate more about gear speeds , see the extension activity on page 4!



E

To make the box, which will house the gears, draw a 45cm by 15cm rectangle on the card. Cut it out with scissors and fold it into 3 equal 15cm by 15cm squares.

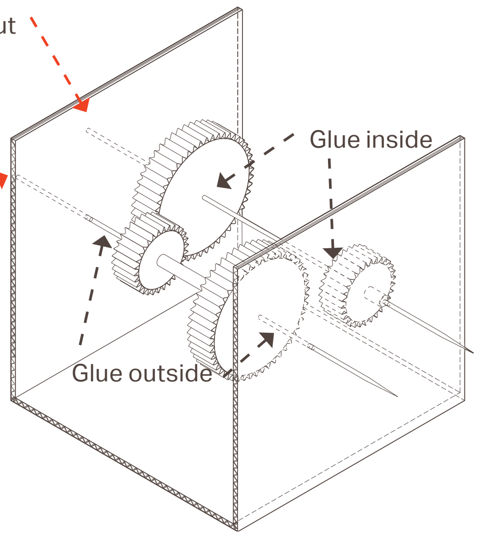
On the two upright sections of cardboard, using the end of a kebab stick, pierce two holes 5cm from the edge and 7cm from the end.



F

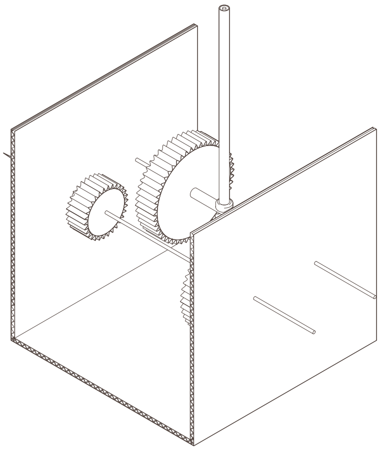
To make the input shaft, push a kebab stick through one of the holes in the box. Before pushing the stick through the hole in the other side, thread on a 1cm long piece of straw, followed by a large wheel, then a small wheel and another 1cm long piece of straw. Push the straws and wheels to the edges of the box. Use hot glue to glue the wheel to the kebab stick but only on the **inside.**

To make the output shaft, push a kebab stick through the other hole. Thread on a small cog, followed by a 5cm long piece of straw and the final large cog. Push the wheels and straw to the centre so they are inside of the wheels on the input shaft. Hot glue the wheels to the kebab stick on the **outside** only.



G

Now, take a 14cm long piece of kebab stick and use hot glue to attach it to the straw on the output shaft. Place a piece of straw the same length over the top and add a little more glue to secure it. This will form the gear stick.

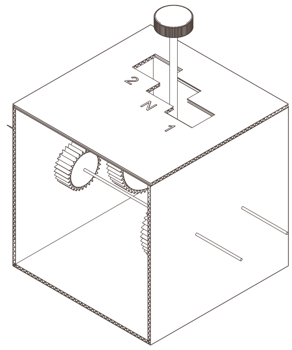


H

To make the lid, measure a 15cm by 15cm square of cardboard. Cut it out and draw on a stepped shape for the gear stick to move within. Label the following:

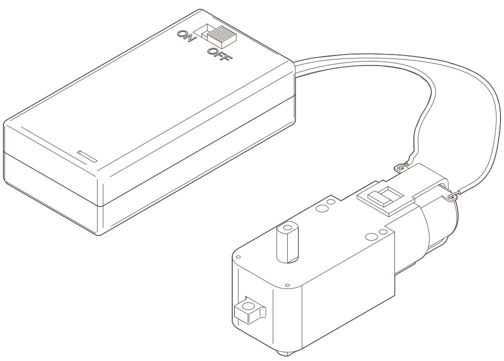
- The point at which the large wheel on the input shaft connects with the small wheel on the output shaft as 2nd gear.
- The space in the middle as neutral.
- The point where the small wheel on the input shaft meets the large wheel on the output shaft as 1st gear.

Hot glue the lid to the gearbox. Then, glue the lid of a plastic bottle to the top of your gear stick to create a handle.



I

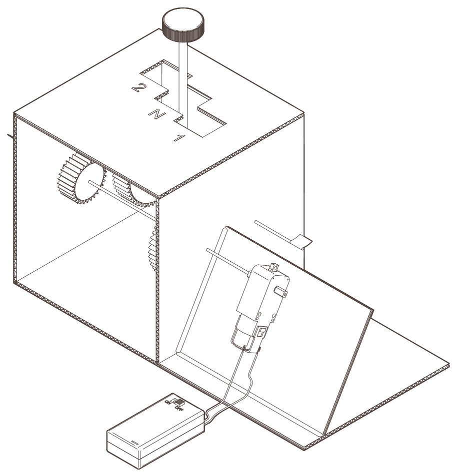
The motor and battery pack will provide the power for the gearbox. To create a complete circuit, electricity needs to travel from the batteries to the motor without any breaks. Carefully, wrap the ends of the wires from the battery pack to the copper connections on the motor, making sure the metal part of the wire is in good contact with the copper.



J

Now, attach the motor to the input shaft. Push the end of the kebab stick into the hole on the side of the motor and use hot glue to secure it. To keep the motor still while it is on, make a bed and shelf for it to sit on using cardboard. Cut out a 15cm by 20cm rectangle and attach it to the bottom of the gearbox. Then connect a smaller piece of cardboard to that and the side of the box at an angle. The motor can be glued to this shelf using hot glue.

Finally, attach a piece of tape to the end of the output shaft. This will highlight the speed at which the shaft is turning so you can see the effect changing gear has.

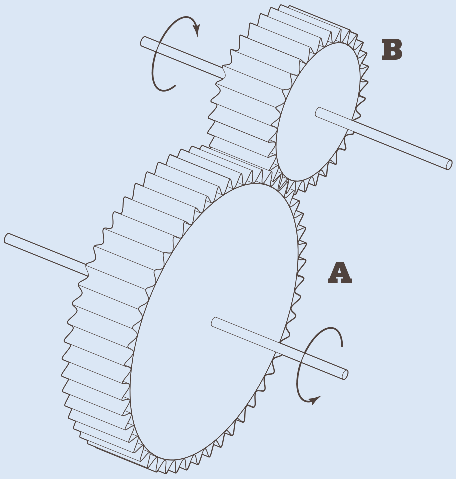


GEARS
TRANSMITTING POWER

20-30m

KS2/3
UNDERSTAND THE SCIENCE

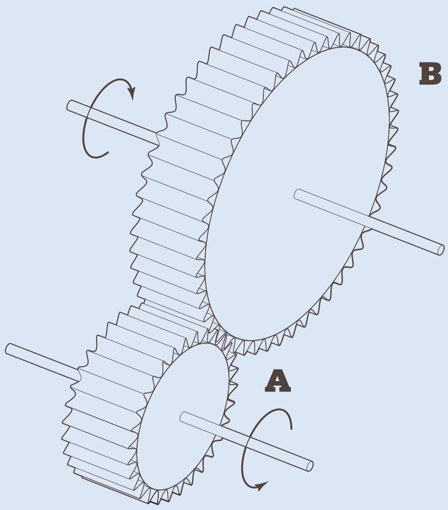
Gears are helpful in machines of all kinds as a way to generate more speed or force. To do any work with a gear, you need to have at least two wheels with teeth that fit together. Because the teeth mesh together, when you turn one gear, the other one turns too.



Having different sized gears can help to either:

Increase speed: If two gears are connected together and the first one (A), has more teeth than the second one (B), the second one has to turn round much faster to keep up. So, the second wheel turns faster than the first one but with less force. This is known as gearing up.

Increase force: If the second wheel in a pair of gears (B), has more teeth than the first one (A), it turns slower than the first one but with more force. This is known as gearing down.



Gears in cars are used to both increase force and speed. If the wheels of a car were connected directly to the drive shaft from the engine, they would always spin at the engines minimum speed (which is usually about 1000rpm) this would correspond to roughly 75mph!

Although that sounds very exciting, there is a problem. It takes a lot of force to get a car moving from standstill. If the engine tried to go at top speed as soon as it was turned on, there would not be enough force to move the heavy vehicle.

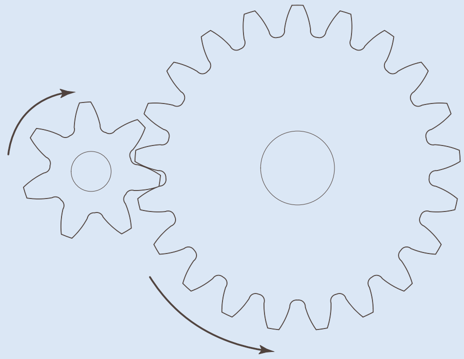
To begin with, drivers need to use a low gear, to generate a lot of force and less speed to get the car moving. Once the car gets going, the driver switches to a higher gear. This means more of the engine's power is used for speed and the car goes faster.

DID YOU KNOW?

Scientists have found a hopping insect called the Issus. It has hind leg joints with interlocking teeth (just like gears) that synchronize the insect's legs when it jumps.

KS3/4
DEEPER LEARNING

The amount a gear system can alter rotational speed is related to the sizes of the gear wheels, and it's known as the gear ratio. To find a gear ratio you count the number of teeth on the output wheel and divide that by the number of teeth on the input wheel, which is the one attached to the motor.



In this example the smaller gear has 7 teeth and the larger 21.

Therefore, they will have a ratio of 7:21 (which is the same as 1:3).

That is to say, the 7-tooth gear will turn 3 times for every one turn of the 21-tooth gear.

This is because each gear needs to rotate by the same number of teeth for them to mesh. So the 7-tooth gear, having one-third of the teeth, needs to turn three times as much.

If you know the gear ratio and the speed input, you can calculate the speed output using the formula:

$$\textit{output speed} = \textit{input speed} \div \textit{gear ratio}$$

For example, if you have a **gear ratio** of 3 (as above) and the **input** gear revolves at 180 RPM, you can work out the output speed:

$$180/3 = 60 \text{ RPM}$$

DID YOU KNOW?

Some historians believe gears date back to at least the 27th Century B.C. when they were used in a chariot in China. However, it was the Greek mathematician Hero of Alexandria who was the first to write specifically about gears in 50 A.D.

QUIZ

15-20m

What piece of equipment can be used to construct circles?

....

....

What is the mathematical term for the distance from the edge to the centre of a circle?

....

....

What features of corrugated cardboard make it suitable for constructing gears?

....

....

What is the name of the Greek mathematician who first wrote about gears?

....

....

In the model gearbox, which of the gears, 1st or 2nd, is an example of gearing up?

....

....

QUIZ

How can you ensure your electrical circuit is complete?

....

....

How does a gearbox help to get a car moving?

....

....

What does the acronym 'RPM' stand for?

....

....

If a cyclist is pedalling with a drive gear of 50 teeth and a driven gear of 10 teeth, what is the gear ratio?

....

....

A driver gear rotating at 120 RPM is connected to a gear arrangement with a ratio of 7:14. Calculate the output speed.

....

....

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ENGINEERING SCHOOL