WOW sheet
Wheel and axle

Together, the wheel and axle are one of the six types of **simple machines**.

A machine is a device that does a physical task. **Simple machines** are the most basic devices that allow work to be done with less effort. A simple machine can change the direction or the magnitude of a force, or the point where the force is applied.

What is a wheel and axle?

A wheel is a circular object that can rotate. An axle is a rod that goes through the centre of the wheel, which the wheel rotates around.
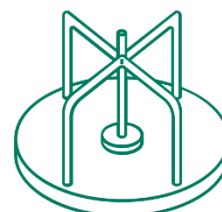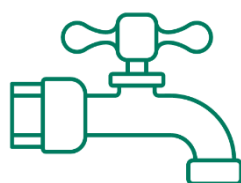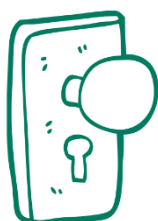
Together, a wheel and axle are a simple machine that can change a small force into a larger one, increase the distance travelled, or reduce friction in movement.

You will find wheels and axles on many types of vehicles, including cars, busses, bicycles, and skateboards.

Other common examples of wheels and axles include:

- doorknobs
- faucets
- playground roundabouts

Why use a wheel and axle?

In a wheel and axle, both parts always work together.

No matter where the force is applied, it will be translated to the other part of the simple machine. In other words, force applied to the wheel will affect the axle and force applied to the axle will affect the wheel.

You can actually think about the wheel and axle as being two different simple machines:

1. A machine where the force is applied to the wheel.
2. A machine where the force is applied to the axle.

These two styles of applying force allow wheels and axles to be used in different ways.

Using a wheel and axle creates a **mechanical advantage** and allows you to get more work done with less effort.

The three main reasons to use a wheel or axle are:

1. Change a small force into a larger one.
2. Increase the distance travelled.
3. Reduce friction in movement.

Change a small force into a larger one

In machines where the force is applied to the wheel, the wheel and axle can change a small force into a larger one.

Because the wheel is bigger than the axle, the wheel turns further than the axle as both parts rotate. In other words, the wheel travels

a longer distance than the axle. Because it travels a shorter distance, the axle turns with a greater force.

This allows you to do work with less effort.

◎ Here's an example

A windmill uses the energy of the wind to turn a wheel made out of sails.

The wind doesn't need to be very strong to turn the wheel.

The wheel is much larger than the axle it is attached to, so the wheel travels a much larger distance each turn. The axle turns a much smaller distance, so it turns with a larger force.

This allows windmills to do work like pumping water, grinding grain into flour, or even spinning a generator to make electricity!
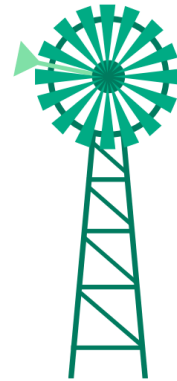
Together, the wheel and axle are a special kind of **lever**, where the centre of the wheel is the fulcrum. Rather than moving in a straight line, however, a wheel and axle rotate.

Again, the wheel travels a greater distance than the axle does each rotation. The axle moves less distance and turns with greater force. This allows a wheel and axle to concentrate a turning force and magnify it on a smaller point.

⊙ Here's an example

A screwdriver is actually a type of wheel and axle.

The handle of the screwdriver acts as the wheel. The shaft of the screwdriver is the axle.

When you turn the handle, both the handle and the shaft turn. Because the handle is bigger than the shaft, it turns further.

That means that the axle moves less distance than the wheel, so it turns with greater force.

The point of the shaft focuses the force from you turning the handle onto a single point: the head of the screw!

Increase the distance travelled

In machines where the force is applied to the axle, the wheel and axle can increase the distance travelled.

When force is applied to turn the axle, the wheel also turns. The force on the axle is spread out over the larger distance of the wheel. The effort to spin the axle is greater, but the result is that the whole wheel travels further.

A Ferris wheel is an amusement ride.

The ride is made of a large upright wheel that rotates around a fixed axle. People sit in special sections which are attached to the rim of the wheel. These passenger areas stay upright as the wheel turns.

A force, usually in the form of a motor, spins the whole Ferris wheel around. This force comes from the axle of the Ferris wheel. As the axle turns, the people riding in the seats travel a large distance. That's what makes it fun!

Many vehicles, including cars, trucks, busses, and trains, all use wheels and axles in this way. The effort is applied to the axle and the wheel is the circular path that the effort travels. It takes force to turn the axle, usually supplied by a motor, but that force is then translated to the wheels which make the whole vehicle travel.

Reduce friction in movement

When an object tries to move across the surface of another object, it is slowed by the force of **friction**.

Friction is the force of resistance to the motion between the two surfaces moving over each other. Wheels and axles can help make moving objects easier by reducing friction.

Whybricks

Sometimes, the axle and wheel are joined and both rotate together. In many cases, however, the axle is fixed in place, and the wheel rotates freely around the axle. This design is very helpful for reducing friction.

◉ Here's an example

Skateboards use wheels that rotate around fixed axles.

These wheels help reduce friction between the skateboard and the ground.

Imagine a skateboard that didn't have any wheels. If you stood on it and kicked-off on the ground, you could probably still get the board to slide. But not very far.

The whole underside of the board would be in contact with the ground, creating a lot of friction. When you add the wheels to the skateboard, only the wheels touch the ground. There is a lot less friction, meaning it takes less effort to move.
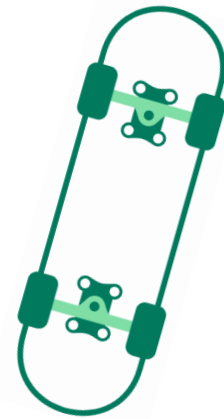
Mechanical advantage of a wheel and axle

You can calculate the mechanical advantage of a wheel and axle by dividing the force of resistance (which is the load) by the force of effort.

$$Mechanical\ Advange = \frac{Force\ of\ resistance}{Force\ of\ effort}$$

When a wheel and axle is reducing friction in movement, dividing the force of resistance by the force of effort will give you the mechanical advantage.

When the wheel and axle is being used to change the magnitude of a force or increase the distance travelled, you can use a different formula. Because the wheel is always larger than the axle, the ideal mechanical advantage (MA) for a wheel and axle is equal to the diameter of the wheel (D) divided by the diameter of the axle (d).

$$MA = \frac{D}{d}$$

◉ Here's an example

Think back to a screwdriver. Remember, in a screwdriver, the handle is the wheel and the shaft is the axle.

Let's say the handle has a diameter (D) of 2.5 mm and the shaft has a diameter (d) of 0.5 mm. That means the mechanical advantage of using the screwdriver is:

$$\frac{2.5mm}{0.5mm} = 5$$

What does that '5' mean? It means that the wheel and axle multiply your input force by 5 times.

You can think of it the opposite way too: however hard you work to turn a screw using your screwdriver, you would have to work 5 times harder without the screwdriver!