New Science Curriculum

Forces: Investigate levers, pulleys and gears used in real situations

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LEVERS

Levers: a simple way of achieving mechanical advantage

Moving a stone using a strong rod is one of the most basic applications of a lever to enable a person to exert more force on an object.

Levers are used to lift heavy weights with the least amount of effort. In the example opposite, the heavy weight is been lifted by the person because of the lever. The longer the 'rod' the easier it is to lift the weight.
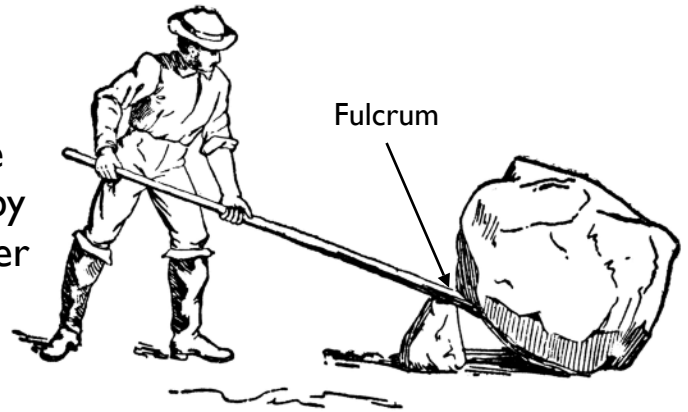
Fulcrum

Under normal circumstances the person would not be able to lift the weight at all. The fulcrum is the place where the rod pivots (or rotates).

The load is the scientific name for the weight. The effort is quite simply the amount of effort used to push down on the rod in order to move the weight.

We use levers in every day life. Bicycle brakes work due to the fact that they are based on a lever.

BRAKE LEVER
EFFORT
FULCRUM
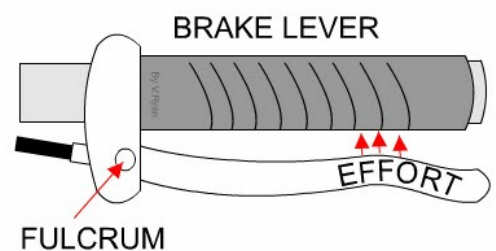
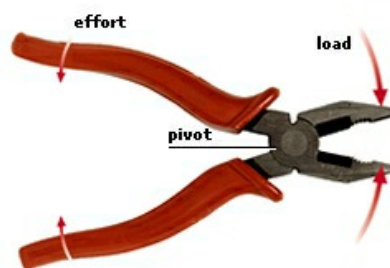Good examples of a lever are a simple door handle or a wheel barrow.

Draw three examples of levers that are used in everyday life.

People consider lever arrangements as falling into one of three classes or 'orders' depending on the relative positions of the fulcrum, load and lifting force.
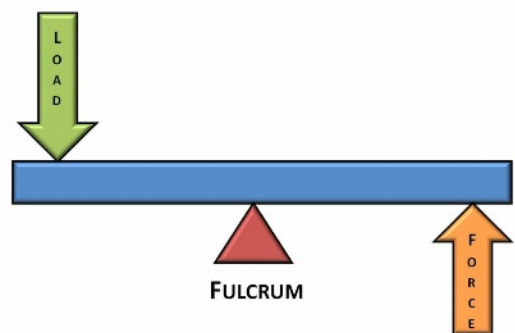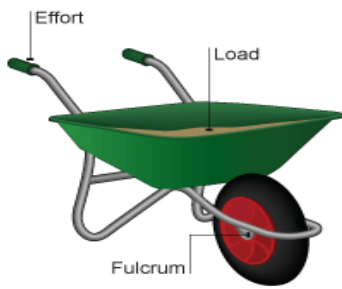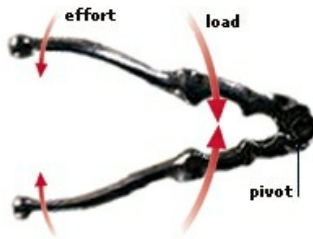
1st Order Levers:

Claw hammer

Pliers

effort   load   pivot
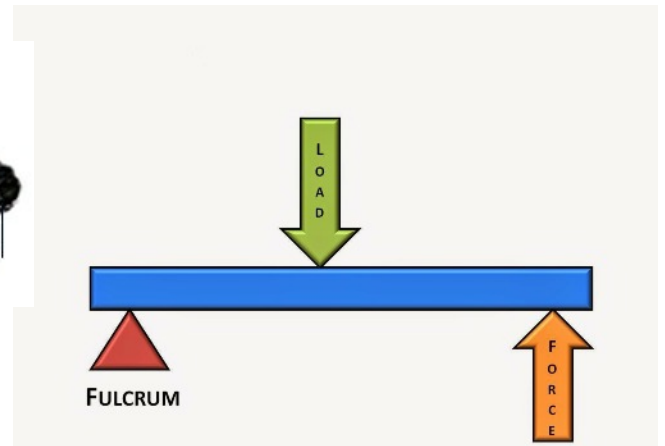
LOAD   FULCRUM   FORCE
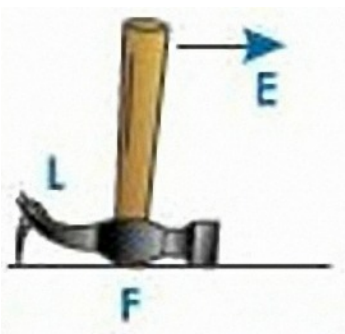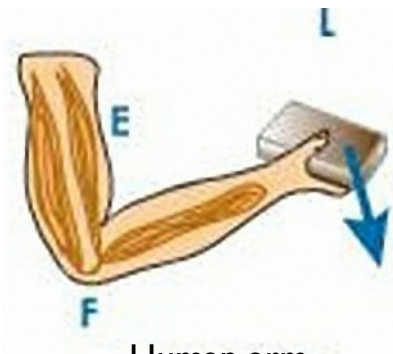
2nd Order Levers:

Wheel barrow

Nut cracker

3rd Order Levers:

Human arm

Tweezers
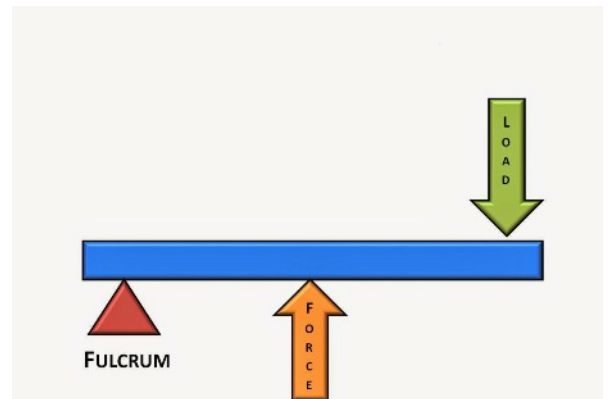
Balancing the forces

Regardless of the order of lever being considered, the same formula applies relating load and the force required to overcome it.

$$M_1 \times a = M_2 \times b$$
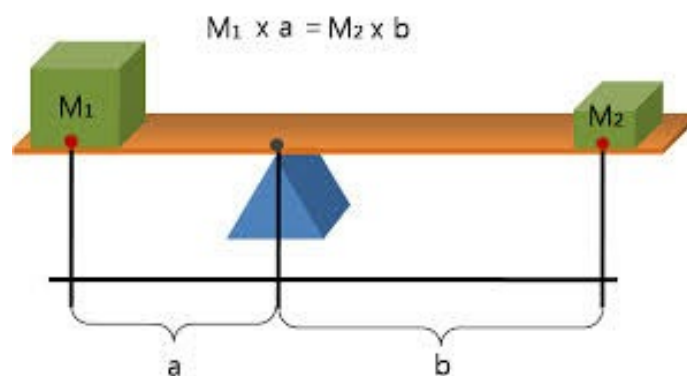
The product of the force and the distance it is applied from the fulcrum must be equal to the product of the effort and the distance from the fulcrum at which it is applied.

Mechanical advantage: for a lever system is the ratio of the two distances from the fulcrum.

PULLEYS

Pulleys: used like levers to lift loads with less effort but for a longer distance

The 1:1 Redirect

Diagram showing a pulley system with a 1:1 ratio is known as a redirect.

In the illustration we have a rope attached to a load weighing 100kg. The rope has been passed through a pulley which is attached to an anchor point and returns back down to ground level.


The amount of effort required to lift the load in this situation is 100kg so we have not formed any mechanical advantage. This system has a ratio of 1:1, additionally for every metre of rope that the user pulls through the system the load will be raised by a metre.

All this system does is change the direction of where the effort needs to be put in, instead of pulling the rope in an upwards direction it can now be pulled downwards which is usually more efficient. This is commonly referred to as a directional or redirect pulley.

In this situation the directional or redirect pulley and its anchor point will actually be feeling double the weight of the load, as there is the load's weight on one side and an effort of 100kg needs to be applied on the other side to raise the load.

The 3:1 Pulley System

Diagram showing a pulley with a 3:1 mechanical advantage.
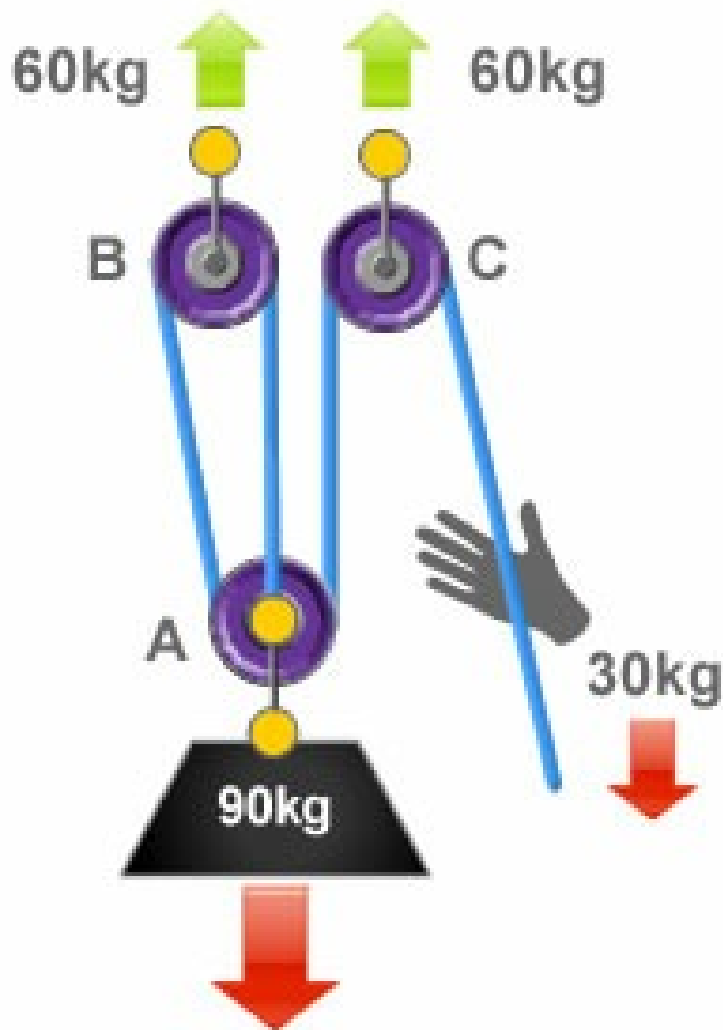
Here we have a 3:1 mechanical advantage. First one end of the rope is attached directly to the load, this is then passed around an anchored pulley (pulley B) and returns back to the load where it is passed through pulley A which has been fixed to the load.

This forms the 3:1 mechanical advantage. Finally the rope is redirected by pulley C back down to the user who applies an effort of 30kg to raise the 90kg load.

An easy way to calculate the ratio of a pulley system is to count the amount of lines that apply effort on the load. In this system there are three ropes that exert effort on to a load of 90kg, so each rope is supporting 1/3 of the load's weight (30kg). Pulleys B & C and their anchors are subject to 60kg each.
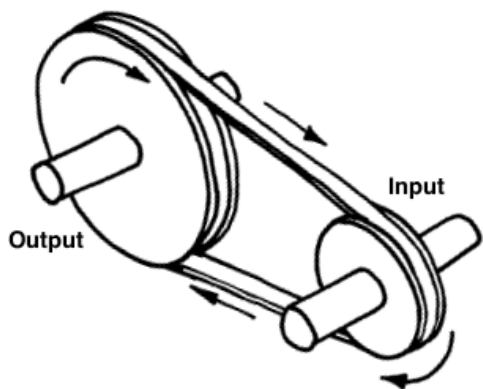
Pulleys: used to change speed or direction of transmission

40mm | **Belt** | **120mm**

100rpm

Driver pulley **Driven pulley**
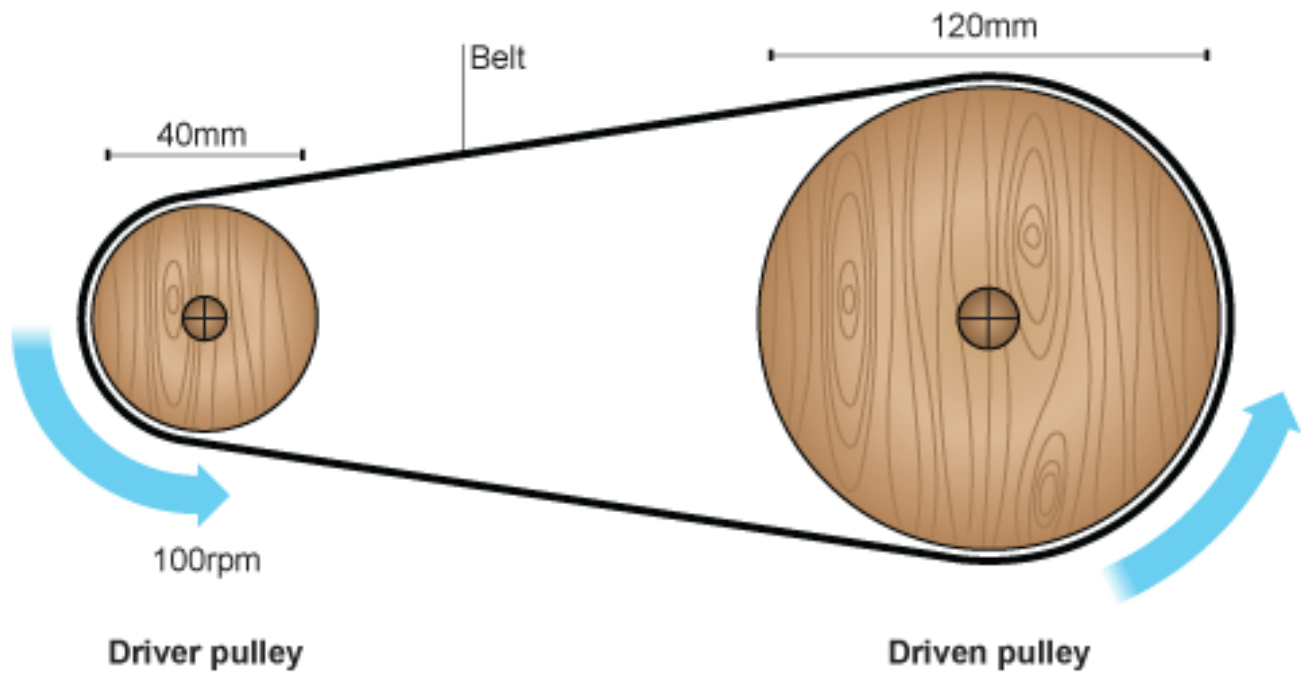
The velocity ratio between two pulleys is determined by their diameters. In this example the driven pulley will rotate three times slower than the drive pulley.

Note that when two pulleys are connected by a belt or chain, the direction of rotation of the driven pulley is the **same** of the drive pulley.


Output **Input**

To reverse the direction of rotation the drive belt can be twisted as shown.

Pulleys are usually used to change the speed of rotation by using different diameter pulleys. As the speed increases so the power delivered decreases. Power can be

lost through friction and elasticity of the drive belt.

Most of the power of the steam beam engine in Combe Mill is transferred throughout the Mill by means of pulleys connected by leather belts.
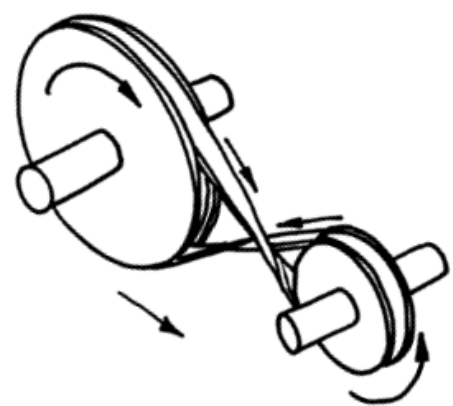
Pulleys and belts can change the direction of
transmission through right angles.
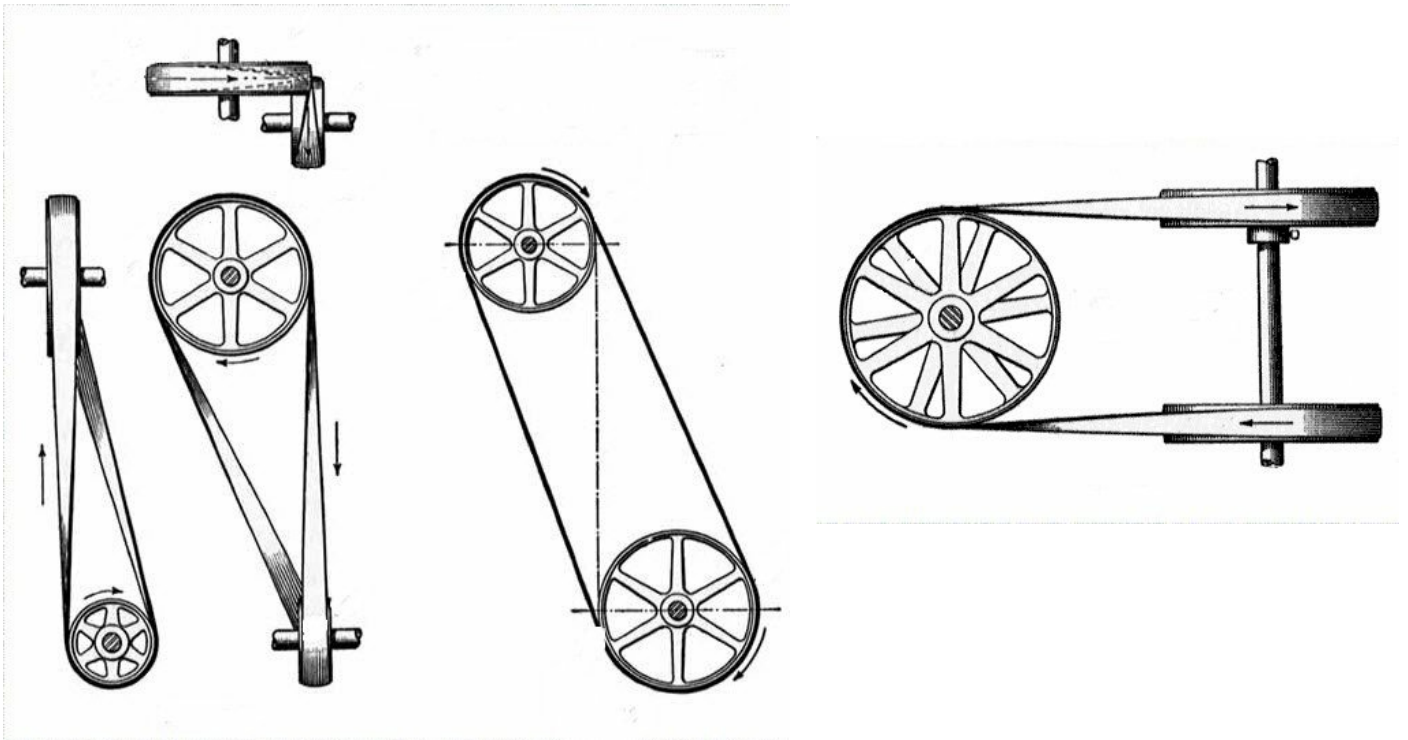
Sometimes instead of connecting pulleys using belts,
the rims of the pulley are made with sprockets and
joined using a chain. While referred to as 'gears' in the
context of a bicycle, they work as pulleys.
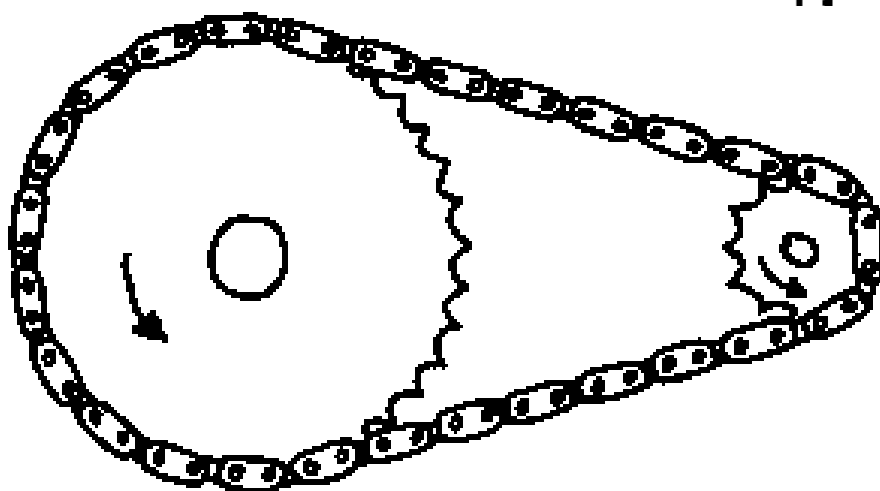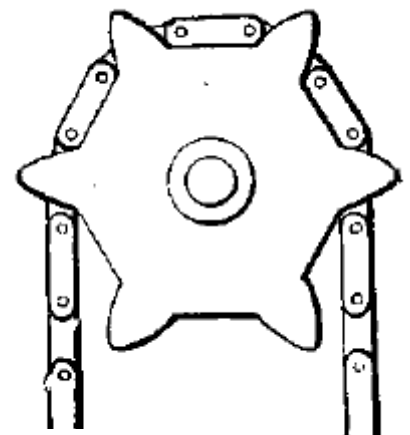
GEARS

What do gears do... and how do they do it?

Gears are used for transmitting power from one part of a machine to another. In a bicycle, for example, it is the gears (with the help of a chain) that take power from the pedals to the back wheel although, strictly speaking, they work as pulleys because the direction of rotation is unchanged.
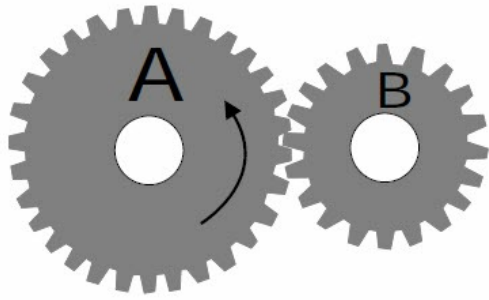
CALCULATE THE RPM OR RATIO BY IGNORING THE CHAIN
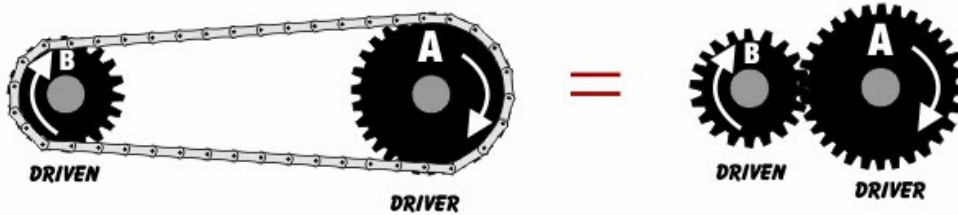
Similarly, in a car, gears transmit power from the crankshaft (the rotating shaft that takes power from the engine) via the drive shaft running under the car that ultimately powers the wheels through the differential.
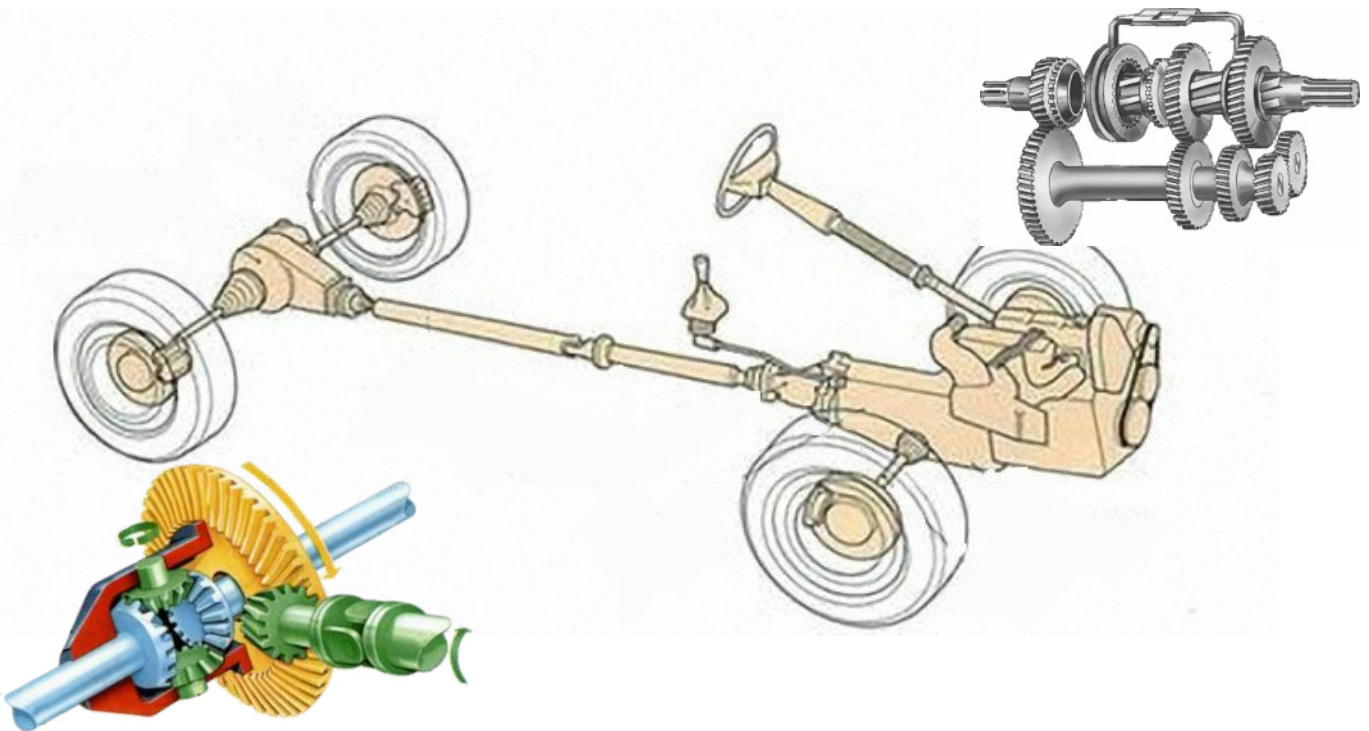
You can have any number of gears connected together and they can be in different shapes and sizes.

It is important to recognise that when gears are in mesh the direction of rotation of the driven gear is the opposite of the drive gear.

Each time you pass power from one gear wheel to another, you can do one of three things:

Increase speed: If you connect two gears together and the first one has more teeth than the second one (generally that means it's a bigger-sized wheel), the second one has to turn round much faster to keep up. So this arrangement means the second wheel turns faster than the first one but with less force.

Increase force: If the second wheel in a pair of gears has more teeth than the first one (that is, if it's a larger wheel), it turns slower than the first one but with more force.

Change direction: When two gears mesh together, the second one always turns in the opposite direction. So if the first one turns clockwise, the second one must turn counterclockwise.

Worm and wheel:

Quite often used in toy cars to drive the wheels from a motor. The worm counts as having just one tooth so the gear ratio can be easily worked out by counting the number of teeth in the mating gear wheel. Look at the steering on the next steam traction engine you see.

An example of a worm and rack gear can be found on the hand mortising machine in the Pattern Shop
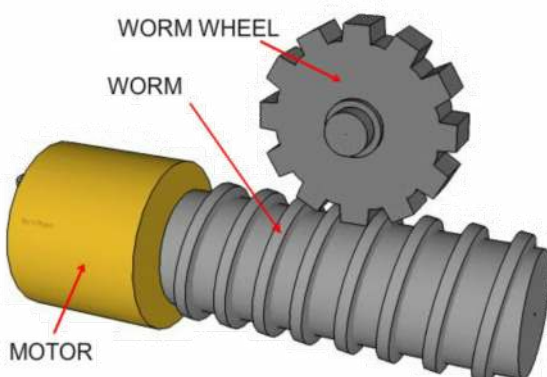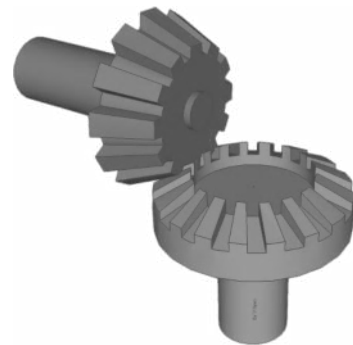
Bevel gears:

Bevel gears are used to change the direction and the common hand drill or kitchen whisk contain good examples.
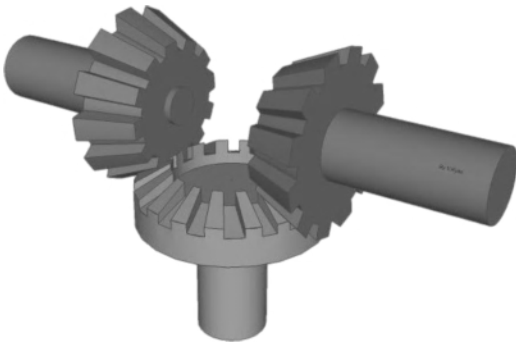
At Combe Mill you can see pairs of bevel gears along the shaft used to adjust the waterwheel sluice from the sawmill.

Rack and pinion gears:

Rack and pinion gearing is used for the steering mechanism on many cars.

It is used to convert rotary movement into linear movement and can be found everywhere from machinery to toys.
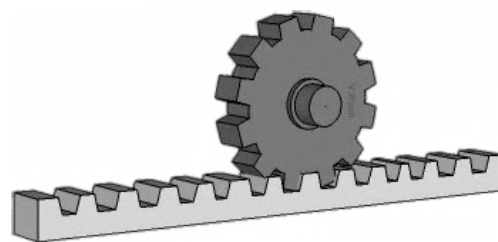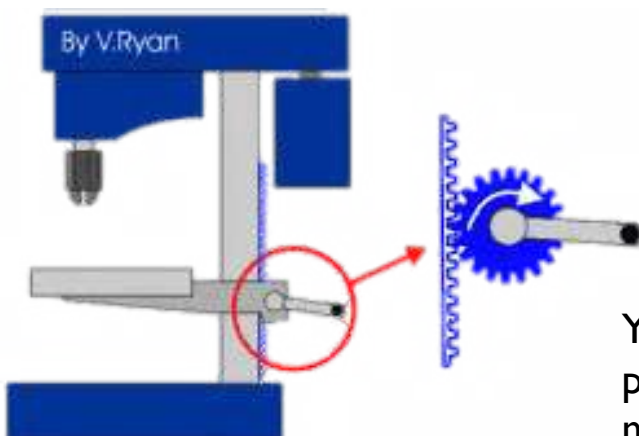
You can find an example of a rack and pinion gear on the work table of our hand mortiser in the Pattern Shop.

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CLOCKS

HOW DO PENDULUMS KEEP CLOCKS ACCURATE?

Look at our working clocks. A weight is raised by winding a handle.

The weight now drops down and its energy is transferred, as kinetic energy, to make the gears turn.

Can you work out what stops the weight dropping quickly back to the floor?

Attached to the pendulum is a device called an 'escapement' to engage the teeth of the gear. This stops the weight dropping back to the floor.

The basic idea is that for each period of the pendulum, one tooth of the gear is allowed to 'escape'.
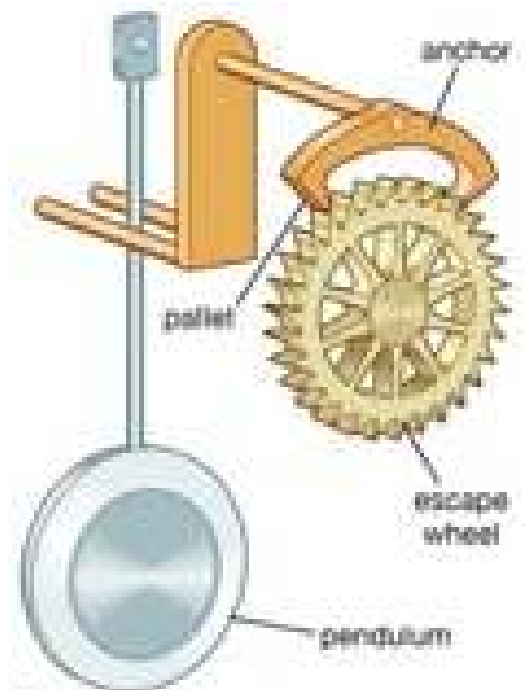
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Most pendulum clocks have a period of 2 seconds, so the escapement wheel moves 30 teeth in 60 seconds. This keeps the clock hands moving accurately; fine adjustments can be made by changing the bob height.

A pendulum will not swing forever. Therefore, one additional job of the escapement wheel is to give just enough energy to the pendulum to overcome friction and allow it to keep swinging.

This gives us the 'tick - tock' sound of a clock!
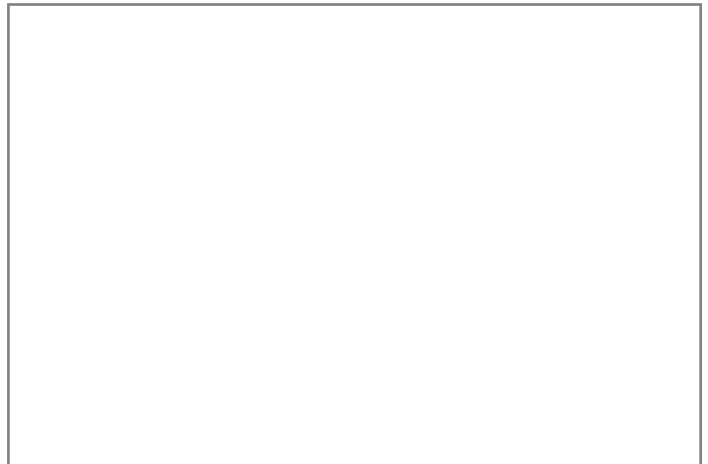
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WORKSHEET

When you have worked through the New Science Curriculum pack you can test yourself by answering the following puzzles that relate to what you can find within Combe Mill.
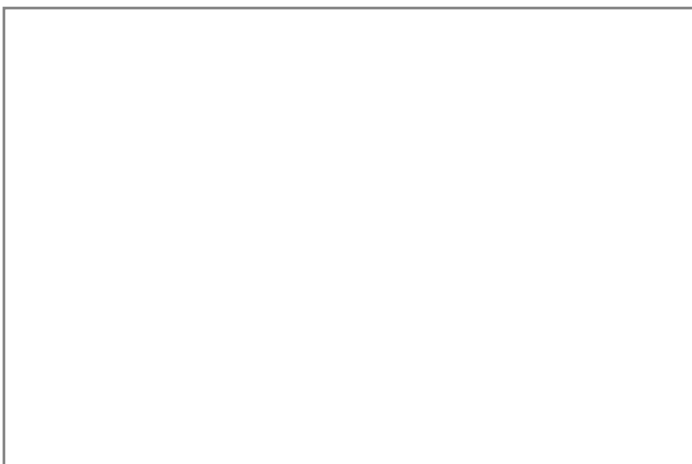
1. Draw three examples of levers that you have seen and say what 'order' of lever each of them demonstrates

This lever is a _____ order lever

This lever is a _____ order lever

This lever is a _____ order lever

2. What would be the relative lengths of the arms of a see-saw if a child weighing 50kg sat on one end and you had to balance them with a 10kg weight at the other end?
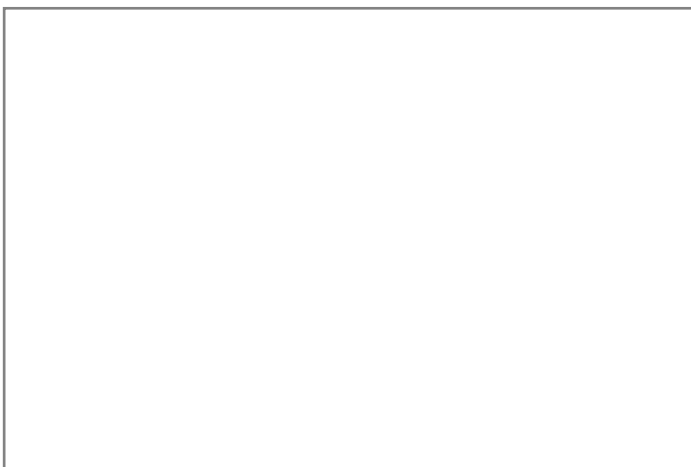
_____

3. Draw a set of gears you have seen in the Mill and describe their purpose. Are they used to change speed or direction?

What is the gear ratio?
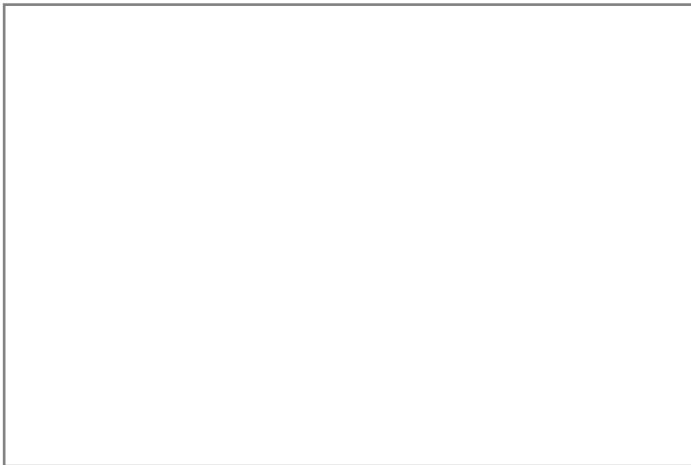
The gears are for …………………….…..

and the gear ratio is ………………

4. Draw a pulley system you have seen in the Mill and describe its purpose. What is the mechanical advantage?

The pulley system is for …………………..…

and the mechanical advantage is ………….