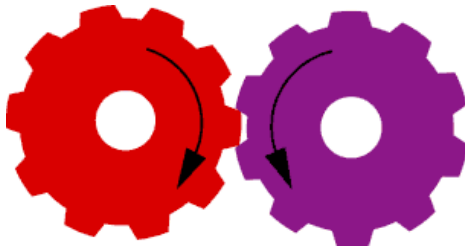


Gears

Gears are wheels with teeth around their edges. The teeth fit together so that when one gear turns, its teeth push against another gear's teeth, causing it to turn as well.

Gears that are next to each other rotate in opposite directions.



Gears in Imagination Factory

There are three gear exhibits in *Questacon Imagination Factory—Invent and Play*. They are:

- Go Go Gears;
- Differential with a Difference; and
- Gear Race

How do gears make life easier?

- When a smaller gear drives a larger gear, the larger gear turns with more force. This is **force magnification**. Lower gears on a bike allow you to apply more force with each turn of the pedals, though you have to pedal more often!
- When a larger gear drives a smaller gear, the smaller gear completes its turns faster. The gears are **magnifying a movement**. When you turn the large gear in egg whisks, it causes smaller gears to spin four times as

quickly. This is fast enough to turn egg whites into foam!

- When a series of gears are joined together, they can transfer motion energy across the whole series.

Quirky Fact

Have you ever seen a penny farthing, an old fashioned bike with one giant front wheel (that is 1.5 m in diameter) and one small wheel?

The wheel is so large because the pedals are directly connected to it. Without any gearing system to magnify movement as you pedal, only a large wheel can generate enough movement to ride at a decent speed.

If not for the power of gear ratios on modern bikes, we might still be riding these bikes today!

Everyday uses of gears

While the word 'gears' tends to bring to mind a circular wheel with teeth, there are actually many different gear shapes out there!

- Standard gears that mesh together in the same plane are known as spur gears. You can find these in mechanical clocks and watches.
- The rack and pinion gear is composed of a circular gear wheel (the pinion) that turns and pushes a long toothed bar (the rack) up or down. The rack and pinion converts circular movement into linear movement. Is it famously used to hoist the frame of a Hills Hoist up and down.
- A worm gear has a circular gear wheel that fits into the spiral grooves along a cylinder. As the spiral cylinder turns, it makes the wheel gear spin. Worm gears are used to reduce the speed of rotation



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greatly and are useful for fine-tuning guitar strings.

- Bevelled gears are shaped like cones that have had their tops cut off. They fit together at an angle and are used to change the direction of rotation. You can find bevelled gears in hand drills, egg whisks and car differentials.

Extras for Experts – Working with Gears

In a gear system, the gear you apply force to is the input gear, while the gear that is driven along is the output gear.

Suppose you have a input gear pushing on a gear of equal size. The gears will turn at the same force and speed (in revolutions per second), although in opposite directions.

What happens if you attach your input gear to a smaller output gear with half the number of teeth?

There are two things to consider – how quickly the output gear will spin as a result, and by how much the force has been magnified.

Movement advantage

You will find that each time the input gear finishes one revolution, the smaller output gear has finished two revolutions because it only has half the number of teeth to be pushed along! The system has gained **movement advantage**.

You can calculate the movement advantage by dividing the number of teeth on the input gear by the number of teeth on the output gear.

Movement advantage =

$$\frac{\text{\# teeth on input gear}}{\text{\# teeth on output gear}}$$

Mechanical advantage

A gear's **mechanical advantage** describes how much your gear system magnifies the force you put into it.

Mechanical advantage =

$$\frac{\text{\# teeth on output gear}}{\text{\# teeth on input gear}}$$

So in our example gear system, the mechanical advantage will be halved, as the output gear has half the teeth of the input gear.

Mechanical vs movement advantage

You may have noticed that the mechanical advantage equation is the inverse of the movement advantage equation!

This means that as movement magnification increases, the force magnification decreases, and vice versa. This is true for all simple machines.

Gear ratios

Sometimes gear systems are described by their gear ratio. It is worked out as follows.

Gear ratio =

$$\text{\# teeth input gear} : \text{\# teeth output gear}$$

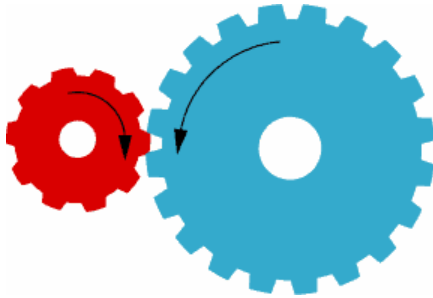
The value you get for a gear ratio closely relates to the amount of movement magnification you will get from your system.

A gear ratio of 1:3 means that for your output gear to complete one revolution, you need to turn your input gear through three revolutions.

Gear ratios don't have to be expressed in whole numbers. For example, the gear ratio of the front and rear set of gears on a bike is 0.73:1, meaning that for every one turn of the pedals, the rear wheel turns 0.73 times.

Examples for Experts

In the following image, the red gear has 10 teeth. The blue gear has 20 teeth.



Maximising mechanical advantage

When the small red gear acts as the input gear, the mechanical advantage is:

$$\begin{aligned} \text{MA} &= 20 / 10 \\ &= 2 \end{aligned}$$

The force has increased by 2 times at the larger gear.

A cyclist experiences this when they move into a lower gear and have to pedal through more turns to move the same distance, but the pedals take less effort to push.

Speeding up with gears

When the large blue gear acts as the input gear, the gear ratio is 20:10, or 2:1. This means the small red gear turns twice for each turn of the blue gear.

This is useful when you want something to spin very quickly. A cook who spins the large gear on an egg whisk is setting in motion a system of gears with a high gear ratio of 4:1. This means that for every one turn of the large gear that is attached to the crank handle, the whisks spin around four times. This saves the cook from having very sore hands!

However, the mechanical advantage = $1/2 = 0.5$. This means the small gear only turns with half the force of the large gear.

For the speed freaks!

If you want to work out exactly how quickly a gear in a system is spinning in terms of revolutions per second, you first have to know how quickly the input gear is spinning, and the number of teeth on each gear.

To work out the speeds, use this formula:

$$\begin{aligned} \text{Output gear's speed} &= \\ &\frac{\text{input gear's speed} \times \text{input gear's teeth}}{\text{output gear's teeth}} \end{aligned}$$

Suppose a gear with 10 teeth is turning a gear with 25 teeth. The small gear is rotating at 5 revolutions per second (rps). The rotation rate of the output gear is as follows:

$$\begin{aligned} \text{Speed} &= \frac{5 \times 10}{25} \\ &= 2 \text{ rps} \end{aligned}$$

Our output gear spins at 2 revolutions per second.

The eLation Electric Bike Conversion Kit – A moving Australian Invention

Riding your bike to school or to work is environmentally friendly and great exercise, but sometimes you need a little bit of help getting up steep hills.

One way to save your legs is to attach a motor to your pushbike so that it can provide some of the driving force.

Bikes that are driven by motors are called electric bikes or power-assisted bikes. The bikes can be bought with the motor attached, or you can use a kit to add a motor to your bike.

Most power assisted bikes work by pushing the bike along by directly driving the rear wheel.

The motor sets the speed of the rear wheel and doesn't take advantage of the bike's own gears to create the most mechanically efficient advantage. Instead, the motors increase force by increasing the speed at which they spin the rear wheel.

Allan Dow, an electronic engineer, decided to invent a new kit that would drive the through the bike's set of gears, allowing you to change gears and therefore maintain maximum efficiency of the motor speed.

An eLating ride

The eLation bike system attaches to a standard bike frame and adds an extra gear to the chain wheels (the front set of gears on a bike that is attached to the pedals).

This gear is connected to the bike by a free wheel clutch. When the clutch is engaged, the eLation motor drives the extra gear and causes the other gears in the chain wheel to rotate.

The force is transmitted through to the rear set of gears by the bike chain, driving the bike along for you.

The rider can also take a rest when the motor is working because the freewheel clutch allows the extra gear to spin without moving the pedals.



The eLation bike system attaches to an extra gear set on a bike's chain wheels. Here the chain linking the motor (the big silver cylinder) to the extra gear is shown. Image used with permission from www.elationbikes.com.au.

The main advantage of the eLation system is that the motor can make use of the bike's gearing system for maximum torque (rotation force) and riding power.

Another advantage of the eLation system is that it gives you three riding styles – you can pedal without interference from the motor, you can run the bike straight off the motor without interference from the pedals, or you can combine the power of pedalling with power from the motor.

While the eLation system can reach speeds of 35 km/h using motor power alone, it can speed up to 55 km/h when the rider pedals while running the motor.

Find out more

About Gears:

- *Visual Science: Mechanics*. John Freeman and Martin Hollins. 1983. 16-17.
- *Hands-On Physics Activities with real-life applications*. James Cunningham and Norman Herr. 1994. 342-345, 349.



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- *The New Way Things Work*. David Macaulay. 1998. 36-47.
- Wikipedia article about gears - <http://en.wikipedia.org/wiki/Gear>
- Wikipedia article about gear ratios - http://en.wikipedia.org/wiki/Gear_ratio

About the eLation bike system

- eLation website - <http://www.elationebikes.com.au/>
- The eLation kit on New Inventors - <http://www.abc.net.au/tv/newinventors/txt/s1781722.htm>