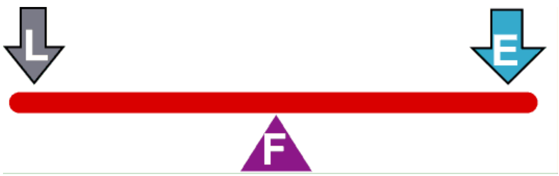
Levers

Levers are usually used to increase effort force so that loads can be moved more easily.

In any lever system, you can identify three parts. They are the:

- effort (the force being put into the lever system)
- load (the object or resistance that the effort force is acting against), and
- fulcrum (the pivot point that the lever turns around).



L is the load force, F is the fulcrum and E is the effort force. The arrows show the direction of each force.

Levers in Imagination Factory

There are two lever exhibits in *Questacon Imagination Factory—Invent and Play*. They are:

- Lifting with Levers
- Levels of Levers

Classes of levers

A lever is known as a 1st, 2nd or 3rd class lever depending on which part-the effort, the load or the fulcrum-is in the middle of the system.

When the fulcrum is in the middle, the lever is a 1st class lever. When the load is in the middle, the lever is a 2nd class lever. 3rd class levers have the effort force in the middle!

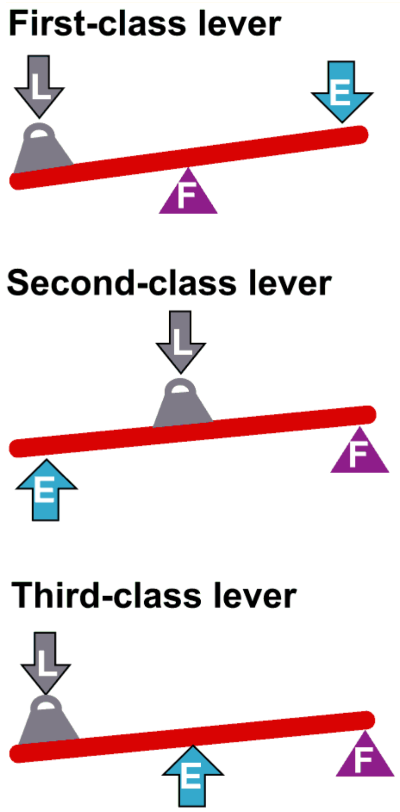
To remember which part is in the middle for each lever class, try using the following rule – "There's a FLE in the middle of my lever!".

The *first* letter is F (for fulcrum in the middle), the *second* letter is L (for load in the middle) and the *third* letter is E (for effort in the middle).

How do levers make life easier?

Each lever class works in particular way to increase effort force or distance.

- First class levers that have uneven load and effort arms can either **magnify force** or **magnify distance**, depending on which arm is longer! They can also be used to change the direction of a force.
- Second class levers can **magnify force**. The longer the lever arm, the greater the force magnification. Try pushing open a door at a point near the door knob, then try pushing it from near the hinge.
- Third class levers **magnify movement**. You use a third class lever when you sweep with a broom. The broom's long handle gives you greater reach for your effort.



The three lever classes.

Quirky Fact

You have two levers working in your jaws! When you bite using your front teeth, such as munching a bite out of an apple, your lower jaw acts as a third class lever.

When you crunch on the apple with your molars, your lower jaw now acts as a second class lever.

Look around for levers

Levers are everywhere, in our homes, on sports fields, on construction sites, on machines and inside our bodies.

First class levers

See-saws, scissors, pliers, balance scales and wheels are all first class levers.

Second class levers

Wheelbarrows, nutcrackers, spanners and doors are all second class levers. All these objects are used to magnify a force.

Third class levers

Spoons, pencils, cricket bats, golf clubs, canoe paddles and broom handles are all third class levers. All these objects are used to magnify movement and give greater reach.

Extras for experts – Working with Levers

When it comes to levers, they're all torque!

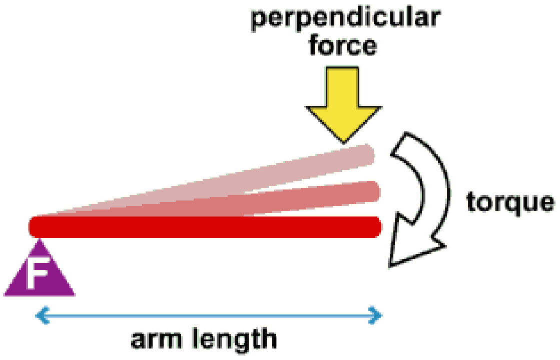
Torque is a rotational force that is influenced by two factors – the length of the arm that's being rotated, and the strength of the force that is acting on the arm from a direction that is perpendicular to the arm.

Torque =
length of arm (m) x perpendicular force (N)

As the length of the arm increases, torque increases. As the applied force increases, torque increases as well. This is true for all three classes of levers.

You can visualise torque by picturing a spanner turning a screw. As the spanner arm gets longer, the screw turns more easily. We often say that we have 'more leverage' when the arm is longer. The screw also turns more easily as you apply more force.

Archimedes, a Greek mathematician, hypothesised that he could move the whole earth if he had a lever long enough and a (presumably) good planet to act as a fulcrum!



Torque is generated as the perpendicular force presses on the lever arm and causes it to rotate.

Examples for experts

Balancing a first class lever

When the torque is even on both arms of a first class lever, the lever will balance.

Because torque is the product of the arm length and the perpendicular force on the arm, the arms don't have to be the same length as long as the forces acting on the arms act to balance out the differences.

The equation for a balancing lever is as follows:

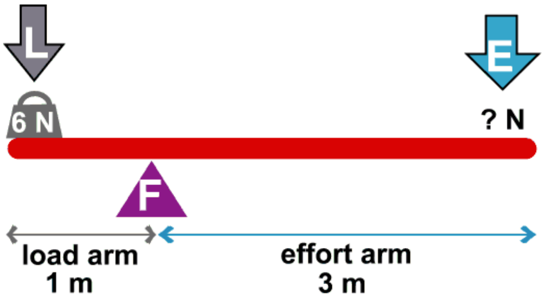
$$Length_{Load} \times Force_{Load} = Length_{Effort} \times Force_{Effort}$$

If the torque on the arms is uneven, the lever will begin to rotate toward the side with less torque.

Lifting with first class levers

A first class lever with a longer effort arm than load arm (so the fulcrum is closer to the load) acts to magnify force by an amount that is proportional to the length of the effort and load arms.

Suppose the effort arm is 3 m long, the load arm is 1 m long and there is a 6 newton (N) load sitting on the arm.



For our lever to balance, we need to work out the following equation.

$$Length_{Load} \times Force_{Load} = Length_{Effort} \times Force_{Effort}$$

$$1\text{ m} \times 6\text{ N} = 3\text{ m} \times Force_{Effort}$$

$$6\text{ N·m} = 3\text{ m} \times Force_{Effort}$$

$$Force_{Effort} = 6\text{ N·m} / 3\text{ m}$$

$$Force_{Effort} = 2\text{ N}$$

Therefore 2 N of effort force is required to balance the 6 N of load force. The system has a mechanical advantage of 3, for a proportionate increase in effort distance.

By rearranging the lever balancing equation, you will see that the proportion of force gained or lost will always equal the proportion of the lengths of the load and effort arms.

$$\frac{Length_{Load}}{Length_{Effort}} = \frac{Force_{Effort}}{Force_{Load}}$$

Lifting (the hard way) with first class levers

What happens if the effort arm is shorter than the load arm? Suppose the effort arm is 2 m long, the load arm is 5 m long and there is 4 N load sitting on the arm.

$$Length_{Load} \times Force_{Load} = Length_{Effort} \times Force_{Effort}$$

$$5\text{ m} \times 4\text{ N} = 2\text{ m} \times Force_{Effort}$$

$$20\text{ N·m} = 2\text{ m} \times Force_{Effort}$$

$$Force_{Effort} = 20\text{ N·m} / 2\text{ m}$$

$$= 10\text{ N}$$

Suddenly we need 10 N of effort to balance the 4 N load force. We have lost mechanical advantage! The upshot is that the longer load arm gives greater reach for the greater effort.

Force vs reach – Second class levers vs Third class levers

Second and third class levers exert torque around their fulcrums. The length of the load arm for these levers is measured from the fulcrum to the point where the effort force is being applied.

Because a second class lever's effort force further from the fulcrum than a third class lever's effort force, a second class lever will have greater torque.

Shinfin™ flippers–An Australian Invention that's making a splash

When you go for a swim in the pool or the ocean, a pair of flippers always comes in handy (or perhaps footy)!

Flippers increase the surface area of our feet so that we can push against more water molecules and create more thrust.

However, because flippers attach to the end of the foot, they often cause the leg to pivot from the knees and ankles, resulting in loss of pushing force and some very sore ankles at the end of a day's swimming

The flipper floppiness also works against you out of the water, making it hard to walk.

After inventor Marc Lee visited the beach and saw bodyboarders struggling to get to the water in their flippers, he decided to invent a new type of flipper that would overcome these problems.

Walking the walk

After working through over 50 prototypes, Marc created the shinfin™ flippers, which flip the whole idea of a flipper around.

The shinfin™ flippers are designed to be worn around the base of the shins, covering the ankles and spreading over the top of the foot instead of underneath it. This makes it much easier to walk around as the flippers keep well out of your way.

shinfin™ flippers strap onto the shins. Image used with permission from www.shinfin.com

Torquing the torque

The shinfin™ flipper also corrects the swimmer's leg action to increase torque.

When you are doing a scissor kick, your legs act as third class levers that pivot from your hips. Your muscles provide the effort and your feet push against the water, which acts as the load force.

According to lever mechanics, the longer the lever arm (or leg in this case), the greater torque force you get. The best scissor kick is one where the legs are mostly straight all the way from the pivoting hips to the feet.

In ordinary flippers, the swimmer often ends up bending from the knee because the flipper's resistance in the water puts too much load on the end of the leg.

So instead of long-legged levers, the swimmer is now using just their lower legs as the levers, with their knees acting as the pivot points. The shorter levers mean that force is reduced.

Because shinfin™ flippers attach at the base of the shin, they place the load of the water's resistance at a much stronger point of the leg. This reduces bending at the knee and helps to lengthen the swimmer's leggy levers.

The swimmer can now generate more force, making for a much more efficient swimming sensation!

Find out more

About Levers:

- *Hands-On Physics Activities with real-life applications*. James Cunningham and Norman Herr. 1994.167-186, 332-333, 346-7, 351.
- *A Measure of All Things*. Ian Whitelaw. 2007.
- *The New Way Things Work*. David Macaulay. 1998. 18-19.
- *Heinemann Interactive Science 3*. Christine Watson. 2005. 106-9.

About shinfin™ flippers

- shinfin™ Website - www.shinfin.com
- New Inventors website - http://www.abc.net.au/tv/newinventors/txt/s1899662.htm