Questacon Imagination Factory invent and play

Background Support Notes

Australian Government Department of Education, Science and Training

Questacon The National Science and Technology Centre

Proudly supported by Raytheon

Pistons – Pneumatics and Hydraulics

Pneumatics and hydraulics describe tubing systems that are filled with a compressed fluid, with pistons at both ends of the fluid.

Pushing in one piston causes pressure to be transferred through the fluid to the other piston, which is pushed out at the same pressure.

A fluid is any substance that flows and fits the shape of its container. This means that gases are fluids!

Pistons that transfer the push through gases (usually compressed air) are called pneumatics, while pistons that transfer the push through liquids (usually oil or water) are called hydraulics.

Pushing on the yellow piston causes the red piston to move out of the tube with equal force.

Pistons in Imagination Factory

There are four piston exhibits in *Questacon Imagination Factory—Invent and Play*. They are:

- Amazing Air
- Manipulator
- Pascal's See Saw
- Pump it Up

Tips for using the exhibits: The compressor in Amazing Air will begin automatically when the air supply begins to run out. You may hear it buzzing for about 30 seconds before it switches off automatically. You can keep playing with the exhibit during this time.

How do pistons make life easier?

Pistons are used in many load-bearing systems.

- Pistons can **transmit force over distances**. In a car, the hydraulic brake system transfers the work your foot does on the brake pad to the car's tyre for you.
- Pistons can **magnify force** when you use a smaller piston to push on a larger piston, but you need to push through a greater distance.
- Pistons can **magnify movement** when you use a larger piston to push on a smaller piston, but you need to push with more force.

Quirky Fact

Engineers have produced a passenger car that runs on compressed air!

The air is stored in a tank in a compressed form. The tank releases bursts of compressed air into the engine, where it expands, pushing down on pistons and providing the engine with power. Standard fuel-based cars use small explosions of fuel and air to push their pistons down.

The 'air car' is going to be introduced in India in 2008, but may need to be safer before it can be used in Australia.

Spot the Pistons around us

You can find pistons in many machines that move heavy loads.

- Bulldozers use pneumatics to lift and swivel the load-carrying blade.

- Track Attack, the roller coaster simulator in Questacon (Canberra), uses pistons to move up, down and around.
- In cars, a hydraulic system transfers the pressure of a foot on the braking pedal to the brake pad.
- Larger vehicles such as buses or trucks often make a hissing sound as they brake to a stop. This is because they use pneumatic brakes (air brakes). Air brakes are preferable because they allow multiple units (such as extra trailers) to be coupled together to the braking system.
- Before telephones and computers became commonplace, large buildings used pneumatic tubes to deliver messages. The written messages were put in small cylindrical containers that slotted into the tubing system and then shot from place to place by air power!

Extras for experts – Working with Pistons

When you use a piston, you're putting it under pressure! To understand how different pistons work, it's important to understand how pressure works.

We define pressure as a force acting over an area. It is measured in newtons (the force) per square metre (the area).

$$\text{Pressure} = \frac{\text{Force (N)}}{\text{Area (m}^2\text{)}}$$

Learning under pressure part 1: Use the force

If you increase the force you put in to a system, you increase the pressure. Push your finger against your palm gently. You are applying a small amount of force to the area of your fingerprint. Now push harder. You are now applying more force to the same area, so you are feeling more pressure!

This makes sense when you look at the pressure equation. The bigger the force value, the greater the pressure will be.

Learning under pressure part 2: A bear's area

You can also change the pressure by changing the area to which you apply the force.

You can see that polar bears understand this when they want to cross an icy patch and don't want to fall through into the freezing water below.

If an adult polar bear moves onto unfamiliar ice, it will lie down and crawl along the ice on its belly, putting as much of its body in contact with the ice as it can.

This increases the area over which the force is spread, reducing the pressure on the ice. The ice is less likely to break and dunk the polar bear!

If the bear decides to stand on the ice, the force of its weight is now working only on the area of its four paws. This increases the pressure on the ice, meaning that the bear could get a surprise bath!

So it looks as if even polar bears understand the pressure equation. As the area value gets bigger, the pressure value decreases.

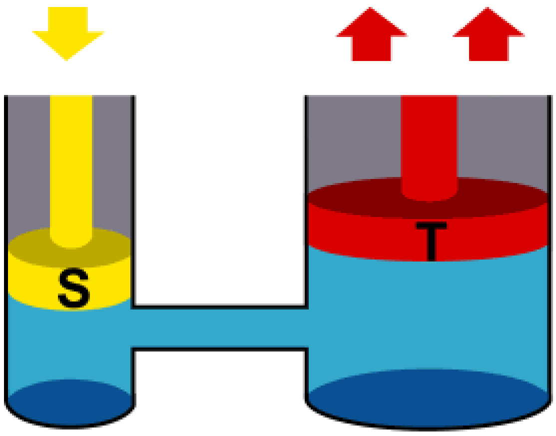
Examples for experts

Pressure, Pistons and Pascal's Principle

If you increase the pressure at one point in a closed fluid system, there is an equal increase in pressure at every other point in the fluid. This is Pascal's principle.

Force magnification

A small piston (piston S) pushing on a piston that is twice its size (piston T) produces twice the force and thus twice the lifting power at piston T's surface.



This is because the pressure is the same throughout the system but there is now two times the area to work on. Hence the total amount of force doubles, balancing the pressure equation. This is **force magnification**.

$$\text{Pressure at piston T} = \frac{\text{Force x 2 (N)}}{\text{Area x 2 }(m^2)}$$

However, because you are moving twice the amount of fluid molecules against piston T's surface, you need to push twice as many fluid molecules toward piston T using piston S. This means that you need to move piston S twice as far for every unit that piston T moves.

So force magnification comes at the expense of a greater effort distance.

Movement magnification

A big piston (piston B) pushing on a piston that is one quarter its size (piston Q) will move the piston Q four times the distance piston B moves.

Piston B is pushing molecules toward the piston Q's surface that is one quarter its size. Piston Q therefore needs to move four times as far to give the molecules the room to move.

This is **movement magnification**.

However, the pressure applied by piston B is now acting on a piston Q's smaller area. Because the pressure is the same at piston Q's smaller surface, the force value is also reduced by the same amount.

$$\text{Pressure at Piston Q} = \frac{\text{Force x } \tfrac{1}{4} \text{ (N)}}{\text{Area x } \tfrac{1}{4} \ (m^2)}$$

This means that movement magnification comes at the expense of force, and you need to put in more force to move the piston a greater distance.

FLAT™–An Australian Invention that uses piston power

If you've ever tried to eat or to work off a wobbly table, you'll know that it can be very annoying! Any movement makes the table rock up and down, which could lead to spilled drinks or messy writing.

Most people fix their wobbly tables by fitting a book under the legs that don't touch the ground, but this takes time and effort each time you need to move the table – and it doesn't look very nice either.

Inventor Tony Pike realised that he could solve this problem by using hydraulic pressure to automatically adjust for any uneveness in the table legs or the ground.

Making a table sit FLAT

FLAT stands for Fluid Locking & Adjustment Technology. Just as its name claims, it makes things sit flat!

Tables that use the FLAT™ system have a small cylinder fitted to the bottom of each leg. The cylinders can slide in and out of the legs like the parts of a folding telescope.

Inside each cylinder is a squishy plastic bladder that is filled with fluid. The bladders are all joined to each other by fluid-filled tubing that runs up the inside of the table legs.

This means that the table actually sits on its own miniature hydraulic system, where the cylinders act as the pistons that push on the bladders and tubing!

When you first put the table down, the telescopic cylinders are pushed up into the table legs by the ground. They push against the bladders, which transfer the pressure of the push equally through the tubing to the bladders and cylinders in the other legs.

The other cylinders are either pushed in or out by the pressure in the hydraulic system. The pressure is equal at all points in the system.

This automatically adjusts the length of each table leg so that all the legs are in contact with the ground – meaning no more wobble.

As the weight of the table presses on them, the system is locked into place by pressure, creating a sturdy surface to snack off!

FLAT™ table legs at work on a sloping surface. The cylinders at the base of the left legs have been pushed out using hydraulic pressure. Image used with permission from www.flat.net.au.

Other devices that could be FLATtened

The FLAT™ system can be fitted to any object that needs stabilisation, such as ladders and helicopters. It can even be put into portaloos. After all, you don't want a portaloo tipping over while you're inside.

The only disadvantage that comes with using FLAT™ is that students will no longer be able to blame their messy handwriting on wobbly tables!

An Excellent addendum

FLAT™ won an Excellence award in the Innovations and Inventions category at the 2006 Engineering Excellence Awards and Best in Show at the 2006 Inpex® Innovations trade show.

Find out more

About Pistons:

- *The New Way Things Work*. David Macaulay. 1998. 126-9.
- Pascal's Principle and Hydraulics – http://www.grc.nasa.gov/WWW/K-12/WindTunnel/Activities/Pascals_principle.html
- *Teaching fluids: intended knowledge and students' actual conceptual evolution*. D. Psillos and P. Kariotoglou. 1999. *Int. J. Sci. Educ.* **21**(1). 17-38.

About compressed air cars:

- Moteur Developpment International - http://www.theaircar.com
- Howstuffworks - http://auto.howstuffworks.com/air-car.htm

About the FLAT system

- FLAT homepage - http://www.flat.net.au/
- New Inventors website article - http://www.abc.net.au/tv/newinventors/txt/s1607733.htm