Pressure

Pressure on surfaces

You may have been warned about swinging around on one leg of a chair. Apart from the risk that you will damage the chair or hurt yourself, the chair leg can damage the floor. This is because it puts too much pressure on the floor.

Calculating pressure

To calculate pressure, you need to know two things:

- the force or weight exerted
- the surface area over which the force or weight is spread

Pressure is calculated using this equation:

pressure = force ÷ area

Example

A force of 20 N acts over an area of 4 m^2. Calculate the pressure.

pressure = force ÷ area = 20 N ÷ 4 m^2 = 5 N/m^2

Notice that the unit of pressure here is N/m^2 (newtons per square metre). Sometimes you will see another unit being used. This is called the pascal and it has the symbol Pa.

1 Pa = 1 N/m^2, so in the example above the pressure is 5 Pa.

Using pressure

If you walk through snow, you usually sink into it. This is because your shoes have a small surface area. Your weight is only spread out over a small area, so the pressure on the snow is high. However, you will not sink so far into the snow if you are on skis. This is because your weight is spread out over a greater surface area, so the pressure on the snow is low.

Drawing pins make good use of different pressures for the same force
Drawing pins have a large round end for your thumb to push. The round end has a large area, so it exerts a low pressure to your thumb. The sharp end has a very small area. The same pushing force produces a high pressure there, so it pushes into the notice board.

If you swing round on one leg of a chair, you put four times as much pressure on one point of the floor as you do if you sit properly. This is because four chair legs spread the pressure over four times more area than one chair leg can.

Pressure in fluids

Liquids and gases are fluids. A fluid is able to change shape and flow from place to place. Fluids exert pressure on surfaces, and this pressure acts at 90° to those surfaces – we say that it acts normal to the surface.

Atmospheric pressure

The atmosphere exerts a pressure on you, and everything around you. You may have seen a demonstration of the effects of this atmospheric pressure.

The Magdeburg hemispheres are two metal cups that fit together. If most of the air is removed from inside them using a vacuum pump, it is almost impossible to pull them apart again. The pressure of the atmosphere acting on their outside surface pushes them tightly together. Once the air is let back in, the pressure inside equals the pressure outside again, and the cups can easily be separated.

RUBBER SEALS BEING USED AS A DEMONSTRATION OF THE MAGDEBURG HEMPISPHERES

The effects of pressure can be seen in the collapsing can experiment. Here some water is boiled in an empty drinks can and steam fills the can. If the can is turned upside down in a trough of cold water, the steam condenses and the air pressure inside goes down. The pressure of the air outside the can suddenly crushes the can.

Atmospheric pressure changes with altitude. The higher you go:

- the lower the weight of the air above you
- the lower the atmospheric pressure

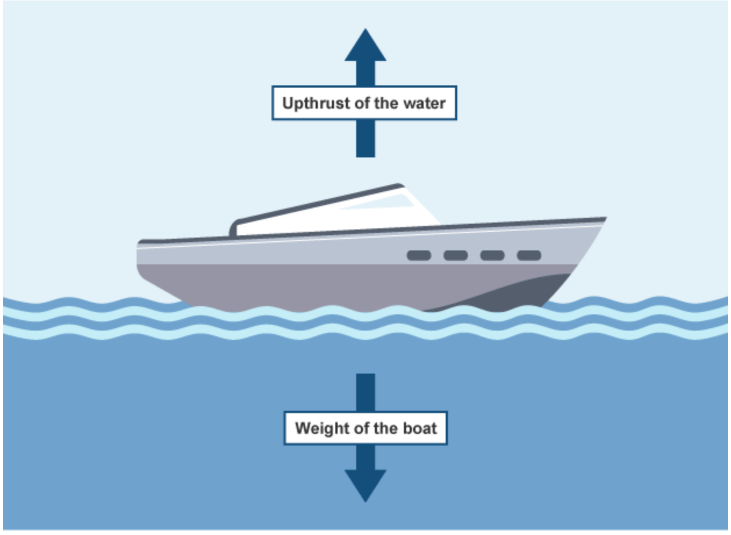
For example, atmospheric pressure at sea level is about 100,000 Pa, but it is only about 21,000 Pa at the cruising height of an airliner.

Pressure in liquids

Just like the atmosphere, liquids exert pressure on objects. The pressure in liquids changes with depth. The deeper you go:

- the greater the weight of liquid above
- the greater the liquid pressure

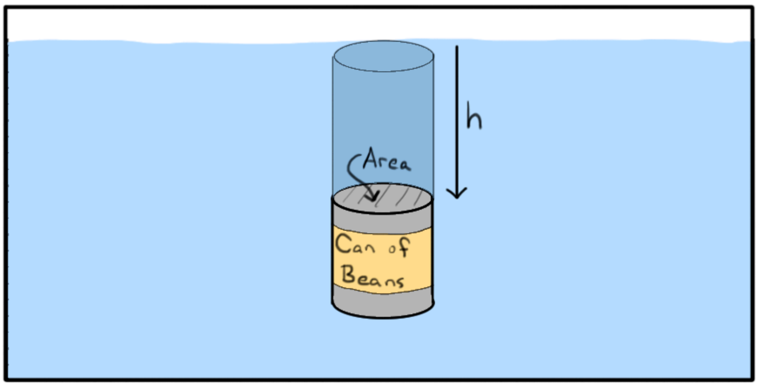
Pressure in a liquid increases with depth so the jet coming from the bottom of the bucket travels further sideways



Liquid pressure is exerted on the surface of an object in a liquid. This pressure causes upthrust. An object placed in a liquid will begin to sink. As it sinks, the liquid pressure on it increases and so the upthrust increases. For a floating object, the upthrust is equal and opposite to the object's weight. An object will continue to sink if its weight is greater than the maximum upthrust.

The weight of the boat is balanced by the upthrust from the water

So the weight of a fluid can exert pressure on objects submerged in it, but how can we determine exactly how much pressure a fluid will exert? Consider a can of beans that got dropped in a pool as seen in the following diagram.



The weight of the column of water above the can of beans is creating pressure at the top of the can. To figure out an expression for the pressure we'll start with the definition of pressure.

$P = F / A$

For the force F we should plug in the weight of the column of water above the can of beans. The weight is always found with $W = m*g$, so the weight of the column of water can be written as $W=m_w*g$ where m_w is the mass of the water column above the beans. We'll plug this into the equation for pressure above and get,

$P = m_w*g / A$

At this point it might not be obvious what to do, but we can simplify this expression by writing m_w in terms of the density and volume of the water. Since density equals mass per unit of volume $\rho = m/V$, we can solve this for the mass of the water column and write $m_w=\rho_w*V_w$ where ρ_w is the density of the water and V_w is the volume of the water column above the can (not the entire volume of the pool). Replacing the mass of the water column into the previous equation we get,

$P = (\rho_w*V_w*g) / A$

At first glance this appears to have only made the formula more complex, but something magical is about to happen. We have volume in the numerator and area in the denominator, so we're going to try to cancel something here to simplify things. We know that the volume of a cylinder is $V=A*h$ where A is the area of the base of the cylinder and h is the height of the cylinder. We can plug V for the volume of water into the previous equation and cancel the areas to get:

$P = (\rho_w*(A*h)*g) / A = \rho_w*h*g$

Not only did we cancel the areas, but we also created a formula that only depends on the density of the water ϱ_w, the depth below the water, and the magnitude of the acceleration due to gravity g.

If you wanted a formula for the total pressure (also called absolute pressure) at the top of the can of beans you would have to add the pressure from the Earth's atmosphere Patm to the pressure from the liquid ϱgh

$$P_{total} = \rho gh + P_{atm}$$

Google Translate Game rules

- Each player must say a sentence of at least five words in English.
- If Google Translate translates it correctly into French, the player wins 5 points
- Each player has two attempts with his set.
- If Google Translate does not understand the second attempt, the player loses three points.
- Each correctly understood scientific word scores 5 points more
- These words add 10 points : pressure, manometer, force, unit, torricelli, barometer, air, water, diving.
- A sentence can be said only once