Pressure in Fluids Notes

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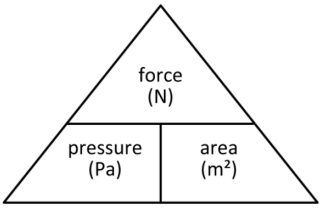
Pressure: is the force that is exerted on an object over a certain area.
The unit of pressure is Pascals which is written as Pa. The equation to calculate pressure is:



Pressure = force ÷ area

Pa = F ÷ a

Exam note on the units of pressure. The most common units for pressure are Pascals which are written as **Pa**. As you can see from the equation above, the equation for pressure shows that to get Pa you need to do the force in newtons divided but the area in meters squared. So, Pa = N/m^2.

But these are not the only units that we could see in a question. We could see a question where we are given the area in centimetres squared. In this case we can give the pressure in newtons per centimetres squared (N/cm^2) but I would like to point out that **N/cm^2 is not equal to Pa** as Pa is N/m^2.

Could a question ask us to convert an area from cm^2 into m^2 so that we are able to give the answer in Pa? **Yes it could**.

Pressure in Gases

Pressure works a little differently in gases compared to liquid. You will need to make sure that you understand the differences between them. What is different about them?

Gases can be compressed – this is due to the large gaps between molecules of gas.

Liquids cannot be compressed – this is due to there being very little space between molecules of liquids.

What actually causes gas pressure? The pressure is caused by the force from particles colliding with the walls of the container. If there are fewer particles in the same volume, there will be fewer collisions with the walls per second, resulting in lower pressure. The opposite is true of course.

At this point it's important to mention Boyle's Law. It comes up here and there in the GCSE but it's very important for understanding relationships between pressure and volume.

Boyle's Law states: that for a gas at a constant temperature, pressure × volume is also constant. So, increasing pressure means that volume will decrease providing that the temperature remains constant.

The equation for Boyle's Law is:

$$\mathbf{P_1 \times V_1 = P_2 \times V_2}$$

$\mathbf{P_1}$ = initial pressure in Pa $\mathbf{V_1}$ = initial volume in (m^3) $\mathbf{P_2}$ = final pressure in Pa $\mathbf{V_2}$ = final volume in (m^3)

What happens if we change the temperature of a fixed volume of gas?

When the temperature is increased, the gas particles move faster and the collisions become stronger and more frequent. This means that the pressure increases. When the temperature is decreased the pressure also decreases.

Pressure in a fluid: is different at different depths. The pressure in a fluid increases as you go down further into it.

This is because the further down we go in a fluid, the greater the weight (which is a force) of the fluid pressing down on us from above. This of course links into the equation for pressure, as pressure is force ÷ area.

What is a fluid? In physics a fluid is anything where the particles can flow. So, both liquids and gases are fluids in physics as they both are made of particles which can flow.

Let's have a look at an exam style question 😊

Example 1: A highland cow has a weight of 5500 N. The area of **each hoof** is 0.032 m^2.
Calculate the average pressure that the highland cow exerts on the ground. Give your answer to 2 significant figures.

Step 1: calculate the area of all four of the cows hooves.

$$0.032\ m^2 \times 4 = 0.128\ m^2$$

Step 2: calculate the pressure by dividing the weight by the area.

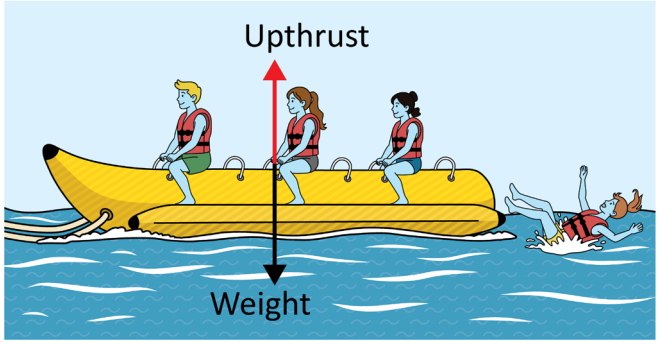
$$\text{Pressure} = 5500 \div 0.128\ m^2$$

$$\text{Pressure} = 42968.75\ \text{Pa}$$

$$\text{Pressure to 2 significant figures} = 43000\ \text{Pa}$$

Upthrust, Floating and Sinking

We know that if we drop an object into a fluid, it will either float or sink. Those are the two options! But, what are the forces involved here, and where do they come from? Let's use an example to go through this. Check out the figure of the banana boat below 😊 Why a banana boat? Why not! 😊



What's upthrust? It's the upward force that a fluid exerts on an object. In the figure above, the upward upthrust perfectly balances the downward weight of the passengers and the boat. Because the forces are balanced there is no resultant force therefore, the boat floats!

Where does upthrust actually come from? This is a classic exam question? We will need to use our knowledge of pressure to explain it:

- We know that pressure in a fluid increases as depth increases.
- Therefore, the pressure pushing up on the bottom of the boat is greater than the pressure pushing down on the top of the boat.
- This difference in pressure creates a resultant force upwards. This is upthrust!

Why do some objects float and others sink? It all comes down to **density**. When an object is placed in a fluid, it pushes some of the fluid out of the way (we call this displacing the fluid).

Floating: If an object is less dense than the fluid it is in, it weighs less than the fluid it has displaced. The upthrust will perfectly equal the object's weight, so it floats.

Sinking: If an object is more dense than the fluid, it weighs more than the fluid it has displaced. The maximum upthrust will be smaller than the object's weight. Because weight is the bigger force, there is a resultant force downwards, so it sinks.

Exam note: if a question asks you to draw a free body diagram of an object sinking, make sure you draw the downward Weight arrow noticeably longer than the upward Upthrust arrow!

Pressure in a column of liquid

We also need to know how to determine the pressure in a column of liquid. Quite a few exam questions involve calculating the pressure in a column of liquid.

The equation to calculate the pressure in a column of liquid is:

pressure = height of column × density of the liquid × gravitational field strength

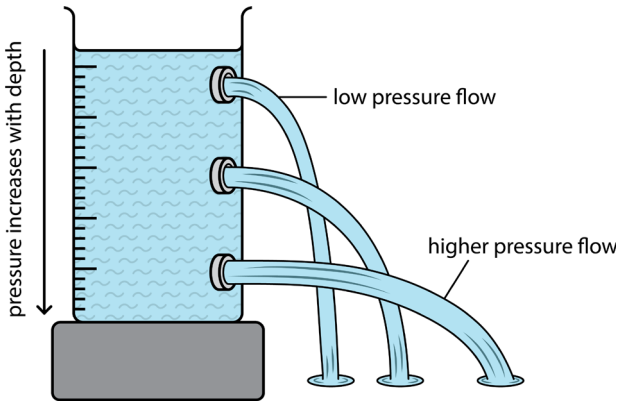
$$\mathbf{p = h \times \rho \times g}$$

Why does the pressure increase as depth increases?
Well, let's remember that pressure is due to weight.

The further down you go in a liquid the more liquid there is above pushing down on the object.

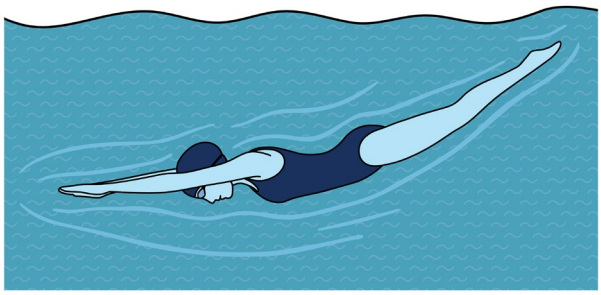
This means as the depth increases the weight increases.

<u>As weight increases so does pressure</u> 😊



Let's have a look at an example.
Example 3: A person swims from a depth of 0.50 m to a depth of 1.70 m below the surface of the sea. Calculate the increase in pressure on the swimmer. Give the unit.

Density of the sea water = 1030 kg/m^3
Gravitational field strength = 9.8 N/kg



Step 1: calculate the increase in depth.

This is just a subtraction 😊

1.7 m – 0.5 m = 1.2 m

Step 2: now we know the change in depth we just need to substitute in the missing values and calculate pressure.

$$P = h \times \rho \times g$$

$$P = 1.2\ m \times 1030 \times 9.8$$

Pressure = 12112.8 Pa

A quick note on atmospheric pressure: <u>The Earth's atmosphere is a thin layer of gas</u>. <u>As the altitude (height) of an object increases, the atmospheric pressure decreases</u>. This is because the air becomes less dense, meaning there are fewer air molecules colliding with surfaces, and less weight of air pressing down from above!