AP Physics 2 – Density & Pressure

Matter: Matter is your basic stuff. You probably agonized over what it was in chemistry. Pretty simple though. Matter is just stuff – anything with mass that takes up space. We often keep track of matter via its mass and the volume it occupies.

Density: An important property of matter is density. Density is defined as mass per unit volume. The symbol for density is ρ.

The equation for density is: $\rho = \frac{m}{V}$

Where ***m*** is the mass, ***V*** is the volume and ρ is the density.

Example Problem

1) A rectangular chunk of granite measures 1.5 m by 0.75 m by 2.5 m. How much does the thing weigh?

First, we can get the density of granite for the table is placed in this handout. Granite's density is 2.7×10^3 kg/m^3. Then let's find the volume of the stone. $V = l\ w\ h$

Solve for the mass:

Find the weight of the stone:

⇨ On occasion you will see the term "_____" which is just the density of the material compared to the density of _____ which is _____ kg/m^3. This ratio has no units. So if the _____ of a substance is ___ then the density is _____ kg/m^3.

Fluids: A ***fluid*** is any material that flows and offers little resistance to changing its shape. Essentially, what we're talking about here, is a gas or liquid. A gas is a collection of very small particles that are rapidly moving around, independently of each other. Gases have an indefinite shape and an indefinite volume.

In a liquid the particles are much closer together and exert attractive forces on each other. The attraction isn't great enough to make the collection rigid, like we would see in a solid, but loose enough so that the particles

can move around fairly freely, but not loose enough that they can easily separate. Thus a liquid can flow, but it all stays together. Liquids have a definite volume and an indefinite shape.

Gases can be compressed or expanded - the volume can be easily changed. This is not true for liquids. _____. This is because they are about as close to one another as they can get so squeezing them together doesn't make much of a difference.

Pressure: There's a good chance that you have studied pressure in a chemistry class, so we'll quickly review the important points about it. Firstly, pressure is a _____ quantity.

Pressure ≡ force per unit area. $\text{Pressure} = \dfrac{\text{Force}}{\text{Area}}$ or

The unit for pressure in the United States is the ***psi***, which stands for ***pounds per square inch*** or ***lb/in^2.*** Other common units are the ***atm***, which stands for atmosphere, and ***inches of mercury***. These are the ones that you probably dealt with in chemistry. We need to get used to _____ which is a _____ in the next unit.

The metric system uses the ***pascal*** which is abbreviated as ***Pa.*** $1\,Pa = 1\dfrac{N}{m^2}$

Example Problems

2) What pressure does a force of 1125 N exert on a surface that measures 2.0 cm by 1.1 cm?

A Pascal is one Newton of force acting upon a 1 square meter surface. Turns out that a Pascal is most definitely small - so the ***kilopascal*** (***kPa***) is commonly used.

3) A water bed is 2.0 m on a side and 30.0 cm deep. (a) Find its weight. (b) Find the pressure that the water bed exerts on the floor.

(a) Hint: Find the mass first!

(b)

Atmospheric pressure is caused by the weight of the air pressing down on the earth's surface. Imagine a column of air that measures one inch by one inch, this means it has a cross sectional area of one square inch. The column soars upward to where the atmosphere ends and the vacuum of space takes over. (This would make it be around 100 000 feet high.) So, imagine weighing this 100 000 foot high by one inch by one inch column on a handy bathroom scale. It would, at sea level, weigh around 14.7 lb.

Its pressure would be: $P = \frac{F}{A}$ $P = \frac{14.7\ lb}{1\ in^2} = 14.7\ psi$

In metric units, a column of air with an area of one square meter weighs 1.013×10^5 N (at sea level). Therefore, atmospheric pressure would be 1.013×10^5 Pa or 1.013×10^2 kPa (or 101.3 kPa).

4) The atmospheric pressure is 1.013×10^2 kPa (You can use 1×10^5 Pa or 1×10^2 kPa on the exam). What force does it exert on the top of a desk that measures 152 cm by 76 cm?

Table of Density Values for Various Substances

Gases	kg/m^3
Air	1.20
Carbon dioxide	1.84
Helium	0.17
Hydrogen	0.084
Methane	0.67
Nitrogen	1.16
Oxygen	1.33
Steam (100°C)	1.99

Substance	*Density kg/m^3*
Alcohol, ethyl	0.791×10^3
Aluminum	2.70×10^3
Copper	8.9×10^3
Gold	19.3×10^3
Granite	2.7×10^3
Ice	0.917×10^3
Brass	4.70×10^3
Iron	7.8×10^3
Silver	10.5×10^3
Lead	11.3×10^3
Mercury	13.6×10^3
Marble	2.7×10^3
Oil	0.85×10^3
Quartz	2.65×10^3
Rubber	1.15×10^3
Seawater	1.025×10^3
Styrofoam	0.10×10^3
Water	1.000×10^3
Wood	0.50×10^3

The study of liquids at rest is called hydrostatics.

If you dive under water, as you get deeper, the _____ above you _____ on you. As you go _____, the pressure _____ - more water above you, right? The pressure increases by roughly 1 atm for every 32 feet of depth.

How does the pressure act on you?

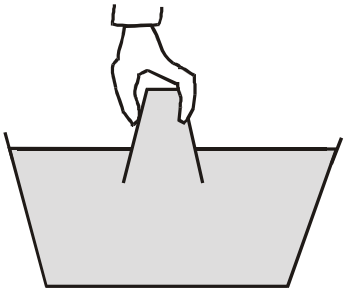
The way a force acts on a solid is different than the way it acts on a fluid. Since a solid is a rigid body, the force does not change its shape. The force mostly tries to ***move*** the object. A liquid cannot sustain a force in this way. Push on the water in a wading pool and you makes a splash – you make the water flow. If the _____ is _____ so that it can't flow, and a force is exerted on it, the force will increase the internal pressure of the fluid. The pressure exerted on a fluid in a closed vessel is transmitted throughout the fluid and _____ at_____ to all _____ that it touches. This is called ***Pascal's Principle***.

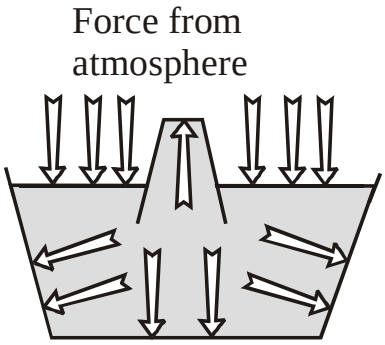
Pascal's principle ≡ The force exerted by a fluid on the walls of its container always acts perpendicular to the walls.

When you are under water the water's pressure pushes in on you from all sides. The force is perpendicular to your body. The clever drawing shows you some of the force vectors acting on the intrepid snorkel diver. (Although she appears to have lost her snorkel.)

The Barometer: The barometer is a device used to measure air pressure.

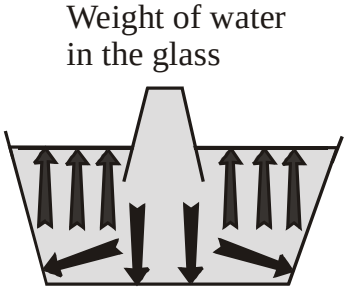
If you fill a glass with water in a tub and then invert the glass and partially pull it out, the water will stay in the glass. Why?





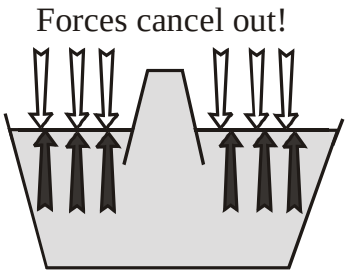
The weight of the atmosphere pushes down on the surface of the water – the old atmospheric pressure. The water in the tub is confined so the pressure exerted on the surface is transmitted throughout the liquid. The pressure exerts a force perpendicular to the surfaces in the tub and in the glass. So the water in the glass is pushed upward.

The water in the glass wants to run out because of its weight, so it exerts a force throughout the water that acts perpendicular to the various surfaces. It acts on the water surface, pushing it up. This can be seen in the lovely drawing to the right.



The effect of this is that the two sets of forces cancel out. The water wants to run out of the glass and raise the surface in the tub but the weight of the air pushes down and that force is greater, so the water is pushed up the glass. We end up with a static column of water in the glass.

This is how a barometer works. The atmosphere can support a tall column of water. If we have a column of air that has a cross sectional area of one square meter, it weighs 1.013 x 10^5 N. It turns out that it can support a column of water of the same cross sectional area so long as the water weighs the same or less than the air. For sea level, this works out to about a ten-meter tall column. This is about 32 feet.



Pressure and Density: When one is swimming under water, the deeper you go, the greater the pressure you are exposed to. The same goes for the atmosphere, the deeper you are in our atmosphere the greater air pressure you feel. Why is this true? _____

_____

This equation is provided on the AP Physics Test. It looks like this:

$$p = p_0 + \rho g h$$

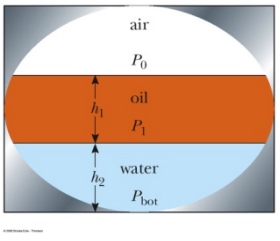
p is the pressure, p_0 simply stands for the initial pressure, ρ is density, and h is depth

The pressure is proportional only to the depth and density of the fluid. The _____ _____ or the object has _____ on _____.

Example Problems

5) What is the pressure exerted by water at a depth of 45.0 m?

In a huge oil tanker, salt water has flooded an oil tank to a depth of 5.0 m. On top of the water is a layer of oil 8.0 m deep. The oil has a density of 700 kg/m^3. (a) Find the pressure at the bottom of the tank if the density of salt water is 1025 kg/m^3. (b) Find the gauge pressure at the bottom of the tank.



(a) You need to find the pressure in at the oil water boundary first.

Next find the pressure using the same equation but the P_o has changed to the pressure found above.

(b) Gauge pressure is simply what would a pressure gauge read . . . remember that we experience the atmospheric pressure normally and a gauge in air would read ZERO!

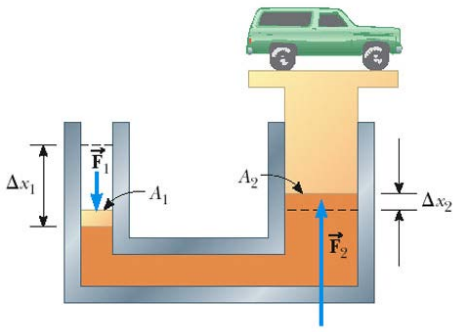
6) (a) Estimate the force exerted on your eardrum due to the water above when you are swimming at the bottom of a pool that is 5.0 m deep. Assume the area of your eardrum is 1 cm^2. (b) What is the net force of your eardrum at that depth?

(a)

(b)

Pascal's Principle AGAIN

A change in pressure applied to an enclosed fluid is transmitted to every point of the fluid and to the walls of the container.



An important application of Pascal's principle is the hydraulic press. The force F_1 is applied to the side with a small area and because the pressure remains the same, that pressure is now applied to the other side with a larger area. The end result is a larger force acting on the car.

$$\frac{F_1}{A_1} = P_1 = P_2 = \frac{F_2}{A_2}$$

7) In a car lift used in a service station, compressed air exerts a force on a small piston of circular cross section having a radius of 5.0 cm. This pressure is transmitted by an incompressible liquid to a second piston or radius 15.0 cm. (a) What force must the compressed air exert of the small piston in order to lift a car weighing 13,300 N? (b) If the car needs to be lifted 1.5 meters, what distance does the small piston need to move?

(a)

(b)