1.1 Fluids & Pressure

Ruptured Fire Hydrant! This guy failed the driver's license certification test.

Side Button for Rabbit Holes!

Pressure: A Can vs. Atmosphere

1. Watch this! What happens to the can, and why?
Write your observations and explanations of the can phenomenon.

Density Review

Density Object's mass a fluid has per volume.

$$density = \frac{mass}{volume}$$

$$\rho = \frac{m}{v_3}$$

AP Equation 1 Resources 3.

SI Unit = kg/m^3 (often units will be g/cm^3)

Density Table 1.1 in your Resources.

Pressure

Fluids move aside when force is applied to a single point of contact, we've got to introduce a new concept: pressure - a force per area.

Mathematically:

Units = N/m^2 = pascal (Pa) $$P = \frac{F}{A}$$

AP Equation 2 Resources 3.

Demo: 100 g mass (1 N) on a 1 m^2 area = 1 Pa.

Remember a Newton (N) equals:

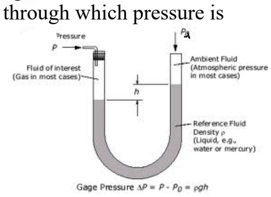
$$N = \frac{kg \bullet m}{s^2}$$

Pressure Measurement

Several devices measure pressure.

You've probably used a spring-loaded tire gauge.

A manometer is a U-shaped tube open to the atmosphere on one end, and connected to a container of gas on the other.
A liquid in the tube acts a reservoir through which pressure is transmitted.
The pressure of the gas is balanced by the weight of the column of liquid and atmospheric pressure.

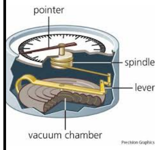


Manometer

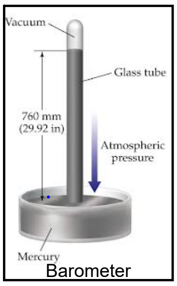
Barometer

A closed tube of Hg is placed upside down in a dish.

Some of the Hg runs into the dish (creating a vacuum above the column), but atmospheric pressure prevents the rest from running out.



Aneroid barometers use a sensitive diaphragm enclosing a vacuum.



Barometer

The Torr

In honor of Evangelista Torricelli, the inventor of the barometer (and successor of Galileo at the academy of science in Florence, Italy), another unit of pressure is named the Torr.

Atmospheric Pressure (P_0)

You are all at the bottom of an enormous ocean of air! The air above you is pushing down, exerting pressure on you.

Atmospheric pressure **(P_0)** changes with weather.
Average: 1 atm = 1.0 E 5 Pa = 1.0 E 5 N/m^2 = 14.7 psi

AP Constant

Absolute pressure is the sum of atmospheric pressure and the pressure of the system, whether it's a block on a table, or water above you while diving.

Gauge pressure (non-absolute) is the pressure of the system only, does not include atmospheric pressure.

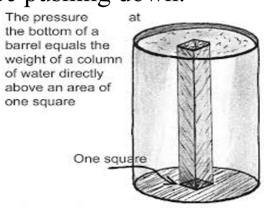
Pressure and Depth

If you've ever swum to the bottom of a pool, you know that pressure increases with depth.

Or, as you've flown in an airplane, your ears have probably popped as pressure differences happened.

The deeper you dive, the taller the column of water above you, so there's more force pushing down.

Pressure at depth is based on force, which depends on the density of the fluid & how tall the fluid column is.



Pressure and Depth Mathematics

The steps:

Force: $F = w = mg$ Density: $\rho = \frac{m}{V}$, $m = \rho V$ Volume: $V = hA$

Substitute: $F = w = mg = \rho V g = \rho g h A$

Pressure: $\frac{F}{A} = P$ $\frac{F}{A} = \rho g h$

Leads to: $\boxed{P = \rho g h}$

To account for atmospheric pressure being applied to the open surface of a liquid: $\boxed{P = P_0 + \rho g h}$

AP Equation 3 Resources 3.

Pressure Equation Unit Analysis

A unit analysis doesn't actually yield N/m^2.
As a test of skill, what base units do you end up with using the pressure equation?

ρ = density (kg/m^3)
g = 9.81 m/s^2
h = height (m)

$$P = \rho g h$$

$$\frac{kg}{m^3} \bullet \frac{m}{s^2} \bullet m = \frac{kg}{m \bullet s^2}$$

To get N/m^2, multiply this odd conglomeration of base units by m/m (which equals 1):

$$\frac{kg}{m \bullet s^2} \bullet \frac{m}{m} = \frac{kg \bullet m}{m^2 s^2} = \frac{kg \bullet m}{s^2} \bullet \frac{1}{m^2} = \frac{N}{m^2}$$

2. Scuba Example A

What is the water pressure alone, and the total pressure on a scuba diver at a depth of 8.0 meters?

$\rho_{H_2O} = 1{,}000\, kg/m^3$

$P_{H_20} = \rho g h$

$= (1{,}000\, kg/m^3)(9.81\, m/s^2)(8.00\, m)$

$= 78{,}000\, N/m^2$

$P = P_0 + P_{H_2O}$

$= 100{,}000\, N/m^2 + 78{,}000\, N/m^2 = 178{,}000\, N/m^2\ (Pa)$

3. Scuba Example B

What force acts on the diver's back (area = 0.300 m^2) at 8.00 m? (From earlier: Pressure = 178,000 N/m^2 (Pa))

$$P = \frac{F}{A}$$

$$F = P \bullet A$$

$$= 178,000\, N/m^2 \bullet 0.300\, m^2 = 54,000\, N$$

That's about 6 tons! Even with atmosphere taken out, it's still about 2.6 tons of water above the diver. How can this be?

The pressure is pushing from all sides, so the diver is not crushed like a grape.

At greater depths, divers ARE crushed like grapes (gory).

https://www.youtube.com/watch?v=LEY3fN4N3D8

4. IV Drip Problem

If the blood pressure (gauge) in a vein is 2,660 Pa, above what height should an intravenous drip bottle be placed for the blood transfusion to function properly?

The density of blood is 1.05 E 3 kg/m^3.

4. IV Drip Problem Answer

Then, the pressure in the vein must be less than the pressure in the IV drip:

$$P_{\rho gh} > P_{vein}$$

So:

$$h > \frac{p_v}{\rho g} = \frac{2.66\,E\,3\,Pa}{(1.05\,E\,3\,kg/m^3)(9.81\,m/s^2)} = 0.259\,m \quad (\approx 26\,cm)$$

Homework 1.1

Read 9.3 in your books

Preview 1.2
Problems 1.1 in your Booklet
Due: Next Class