Fluid Mechanics: Hydrostatic Pressure

Name: ____________________ Period: 2nd Date: ________

Density: $[\rho]$ $\rho = \frac{m}{V}$

Units: $\left[\frac{kg}{m^3}, \frac{g}{cm^3}\right]$

Density of Water:

$\rho_w = 1000 \frac{kg}{m^3} = 1 \frac{g}{cm^3}$

Specific Gravity: ratio used to identify materials by using water as ref.

Units: $S.G = \frac{\rho_{substance}}{\rho_{water}}$

No unit!

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

Units:

$\frac{N}{m^2}$ = Pascal, Pa

Ex1: What is the density of a box that is 1.2 m by 2.5 m by 3.0 m and weighs 50 N?

$V = l \cdot w \cdot h = (1.2)(2.5)(3) = 9\,m^3$

$w = \frac{50N}{10} = 5kg$

$\rho = \frac{m}{V} = \frac{5kg}{9m^3} = 0.56 \frac{kg}{m^3}$

Ex1: What is the specific gravity of aluminum if its density is 2700 kilogram/meter cubed?

$S.G = \frac{2700\,kg/m^3}{1000\,kg/m^3}$

$S.G = 2.7$

Ex1: If the area of a person's shoes is $0.010\ m^2$ and the person's mass is 53 kg, what pressure is being exerted on the box in the area under the feet?

$P = \frac{F}{A} = \frac{(53kg)(10)}{.010}$

$P = 53{,}000\,Pa = 53\,KPa$

Ex2: If the density of a gas is 1.5 grams per centimeter cubed what is its density in kilograms per meter cubed?

$\frac{1.5g}{cm^3} \cdot \frac{1\,kg}{1000g} \cdot \left[\frac{100cm}{1m}\right]^3$

$= 1500 \frac{kg}{m^3}$

Derivation

Use the example with the fish swimming underwater to derive a new expression for pressure at a certain depth.

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

P= F / A

F= $m \cdot g = \rho \cdot V \cdot g = \rho A h g$

m= $\rho \cdot V$

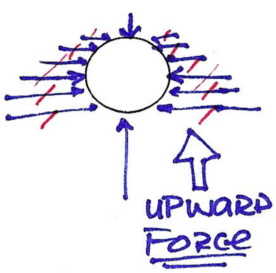
V= $A \cdot h$

$P_{Liq} = \rho g h$

Example: What is the pressure felt by the fish? 5m under the surface

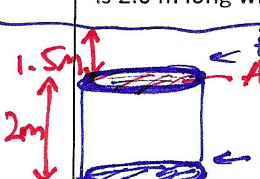
$P_{Liq} = \rho g h = (1000)(10)(5) = 50{,}000\,Pa = 50 \times 10^3\,Pa$ = 50 KPa

A balloon is immersed in a liquid



- The pressure
- The force on the object due to the pressure is directed perpendicular to the surface of the balloon.
- Fluids such as water (or any other liquid) are incompressible and so their density can be taken as a constant
- Note that the pressure on... the lower part is higher than that on the upper part.

Example: What is the difference in pressure between the top and bottom of a cylinder that is under water? The area of the top and bottom is $1.0\ m^2$, the cylinder is 2.0 m long with the top 1.5 m below the surface of the water.



$P_1 = \rho g h = (1000)(10)(1.5) = 15{,}000\,Pa = 15\,KPa$

$P_2 = \rho g h = (1000)(10)(3.5) = 35{,}000\,Pa = 35\,KPa$

$\Delta P = P_2 - P_1 = 35KPa - 15KPa = 20KPa$

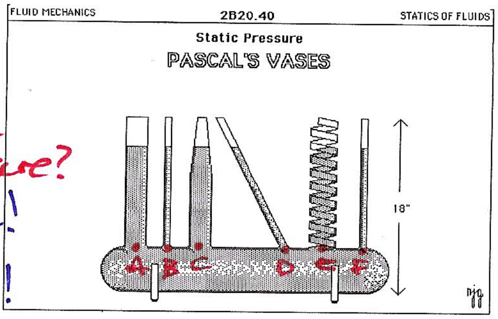
Note that under standard conditions ***air pressure*** is:

$1atm = 1 \times 10^5\,Pa$

atmospheric pressure

P_o = atmospheric pressure

The hydrostatic pressure due to the liquid depends only on the density of the liquid and the depth below the surface. The shape of the container doesn't matter [same depth, same pressure at any point on the liquid].



Greater pressure?
SAME!
Same depth!

The difference between total pressure and atmospheric pressure (P_o) is known as the **GAUGE PRESSURE.**

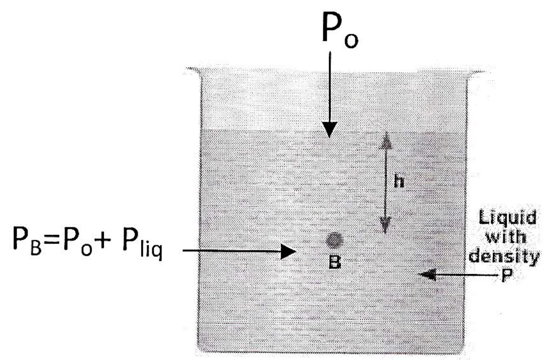
$$P_{gauge} = P - P_o$$

Atmospheric pressure

Pressure without the atmospheric pressure

ATMOSPHERIC PRESSURE

If the liquid in the tank were open to the atmosphere, then the total (or absolute) pressure at depth h, would be equal to the pressure pushing down on the surface- the atmospheric pressure, P_o plus the pressure due to the liquid alone: $P_{total} = P_o + P_{Liq}$

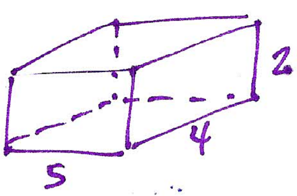


$Po = 1\ atm = 1.013 \times 10^5$ Pa
$= 1 \times 10^5$ Pa

Ex1. A 5mX4mX2m pool is full of water.

a. What is the hydrostatic pressure at the bottom of the surface? (Include atmospheric pressure)

b. How much force is applied on the bottom surface area of the pool?

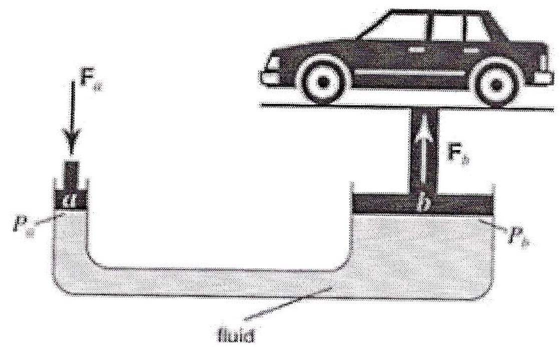


$P_{ABS} = P_W + P_o$
$P_{ABS} = \rho g h + P_o$
$P_{ABS} = (1000)(10)(2) + 1 \times 10^5$
$P_{ABS} = 1.2 \times 10^5$ Pa

Example: What is the pressure at 35 m depth of water for average conditions? Do not neglect atmospheric pressure.

$P_{ABS} = P_o + P_W$
$P_{ABS} = 1 \times 10^5 + (1000)(10)(35)$
$P_{ABS} = 4.5 \times 10^5$ Pa

PASCAL'S PRINCIPLE



States that when a pressure is applied to an enclosed fluid, the pressure is transmitted undiminished to every point of the fluid and to the walls of the containing vessel.

Pascal's Principle: An increase in pressure

The force on the small piston is multiplied by...

The narrow piston must move a...

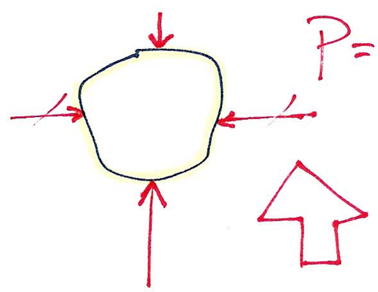
Example: Suppose that the area of the small piston is 50cm^2 and it is pushed with a force of 50 N. How much force is exerted upward by the large piston with an area of 2.0 m^2?

VIDEO:

http://ia600409.us.archive.org/20/items/AP_Physics_B_Lesson_21/Container.html

Hydrostatic Pressure

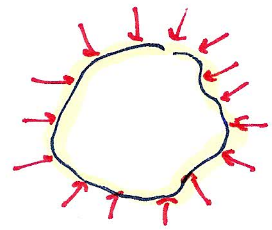
Water



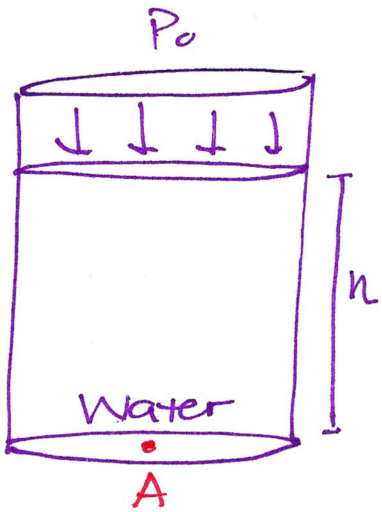
$P = \rho g h$

Air

$P_0 = 1 \times 10^5\,Pa$



CONSTANT pressure all around!



Absolute Pressure → Includes Atmospheric pressure

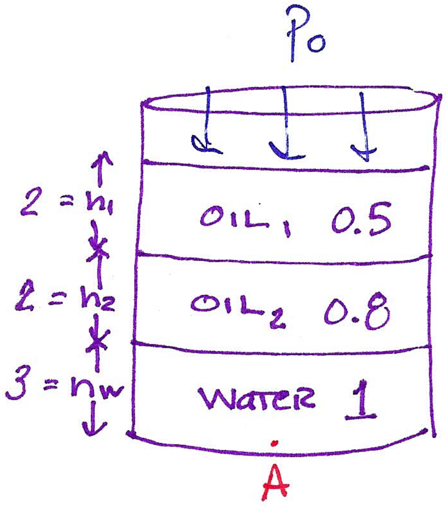
$P_{ABS_A} = P_0 + P_{LIQ}$

$P_{ABS_A} = P_0 + \rho g h$

Gauge Pressure → Doesn't include Atmospheric pressure!

$P_{Gauge} = P_{LIQ}$

$P_{Gauge} = \rho g h$



$P_{ABS_A} = P_0 + P_{OIL_1} + P_{OIL_2} + P_W$

$P_{ABS_A} = P_0 + \rho g h_1 + \rho g h_2 + \rho g h_W$

(ρ → 500 Kg/m³; g → 9.8 m/s²; h_1 → m)