

# Chapter 11 Fluids

**Fluid** - any substance that can be compressed with added pressure

ex: air and water



Check Q?  
Why does the cartesian diver sink?

**Mass Density** = rho =  $\rho$

- Mass per volume (for fluids AND solids)
- Can change for a given liquid due to pressure

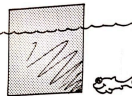
$\rho = m/V$  m = mass (kg), V = volume (m<sup>3</sup>)  
units = kg/m<sup>3</sup>

**Specific Gravity** = sg = density compared to water ... NOT UNITS

- sg = 1 for water..if sg > 1 = sinks, if sg < 1 = floats

Check Q?

THE DENSITY OF THE BLOCK OF WOOD FLOATING IN WATER IS



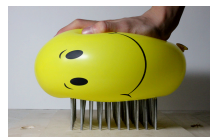
- GREATER THAN THE DENSITY OF WATER
- EQUAL TO THE DENSITY OF WATER
- LESS THAN HALF THAT OF WATER
- MORE THAN HALF THE DENSITY OF WATER
- ... NOT ENOUGH INFORMATION IS GIVEN

Pressure vs Force - Bed of Nails Demo

**Pressure** = force per area

$P = F/A$

units = N/m<sup>2</sup> = Pascals = Pa



P is INVERSELY proportional to area

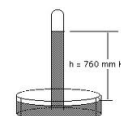
\*\*\*P is NOT a vector!

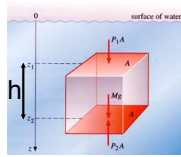
\*\*\*ALWAYS acts  $\perp$  to surface

Soda Can Demo

**Normal atmospheric pressure**

- 1 atm (used in Chemistry)
- **1 x 10<sup>5</sup> Pa** (This is what we use)
- 760 mmHg
- 14.7 lbs/in<sup>2</sup> = psi





Floating Cube in water

$$\sum F_y = F_2 - F_1 - Mg = P_2A - P_1A - Mg = 0$$

since  $V = Ah$  then  $m = \rho V = \rho Ah$

so...

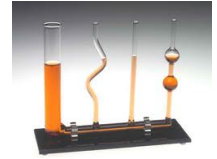
$$P_2A - P_1A = \rho Ahg \text{ and the A's cancel}$$

$$P_2 = P_1 + \rho gh \text{ OR } \Delta P = \rho gh$$

\*\*\*Side pressure cancel!

\*\*\*only HEIGHT of liquid ABOVE point determines pressure!!!!

Demo - equilibrium tubes



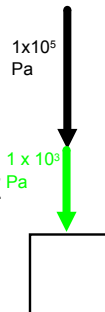
**Absolute vs Gauge pressure**

**Absolute Pressure** = TOTAL

Pressure = add them all up

**Gauge Pressure** = pressure ABOVE

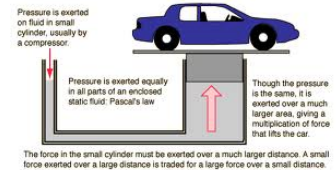
ATM pressure



**Pascal's Principle**

Any change in pressure is applied to all parts of a fluid undiminished if **completely enclosed**

$$F_1/A_1 = F_2/A_2$$

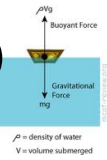


**Archimedes Principle**

Buoyant force is equal to the weight of the volume of liquid displaced

$$F_b = mg_o = \rho V g_o$$

$l = \text{liquid}$   
 $o = \text{object}$

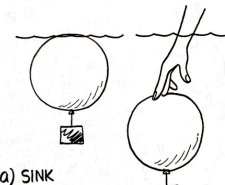


IF  $F_b = mg_o$  then floats

\*\*\*note  $F_b$  does not HAVE to =  $mg_o$

Check Q?

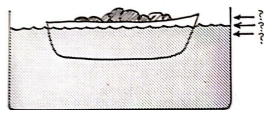
CONSIDER AN AIR-FILLED BALLOON WEIGHTED SO THAT IT IS ON THE VERGE OF SINKING --- THAT IS, ITS OVERALL DENSITY JUST EQUALS THAT OF WATER. NOW IF YOU PUSH IT BENEATH THE SURFACE, IT WILL



- a) SINK
- b) RETURN TO THE SURFACE
- c) STAY AT THE DEPTH TO WHICH IT IS PUSHED

Check Q?

CONSIDER A BOAT LOADED WITH SCRAP IRON IN A SWIMMING POOL. IF THE IRON IS THROWN OVERBOARD INTO THE POOL, WILL THE WATER LEVEL AT THE EDGE OF THE POOL RISE, FALL, OR REMAIN UNCHANGED?

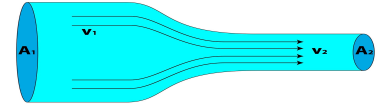


**Law of Continuity**

For a non-compressible liquid the volume flow rate must remain constant

$$A_1v_1 = A_2v_2 = Q = \text{volume flow rate}$$

units = m<sup>3</sup>/s



Demos

- ping pong ball and hair dryer
- ball and box
- paper and blowing

**Bernoulli's Equation**

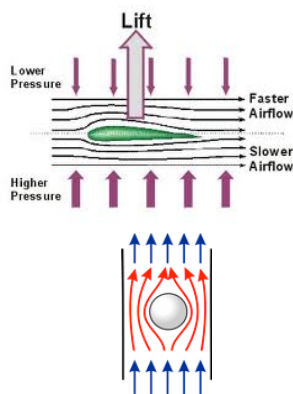
-conservation of energy

Types of energy: "pressure", gravitational potential, and kinetic

$$P_1 + U_{g0} + KE_o = P_2 + U_{gf} + KE_f$$

$$P_1 + \rho gh_o + 1/2\rho v_o^2 = P_2 + \rho gh_f + 1/2\rho v_f^2$$

means if v ↑ then P ↓



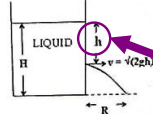
**Toricelli's theorem** - bottle with hole demo

Bernoulli's EQ with following assumptions

- 1) Fluid is moving slowly at top relative to hole at bottom
- 2) pressure is equal at top and hole

$$P_1 + \rho gh_o + 1/2\rho v_o^2 = P_2 + \rho gh_f + 1/2\rho v_f^2$$

$$\rho gh_o = 1/2\rho v_f^2$$



h = height of liquid ABOVE hole!!!

**Poiseuille principle -** (Pwah-zah)

(for viscous fluid "thick")

key concepts (Q = vol flow rate)

\* more viscous = slower flow

\* bigger area = faster flow

\* bigger  $\Delta P$  = faster flow

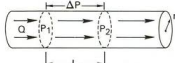
$$Q = \frac{\pi R^4 (P_2 - P_1)}{8 \eta L}$$

$\eta$  = eta = coefficient of viscosity  
(units = Pa s = Poise = P)

ideal fluid = 0 P = infinite flow rate

L = length of "pipe"

R = radius of end of "pipe"



POISEUILLE'S LAW

$$Q = \frac{\Delta P r^4 \pi}{\eta L 8}$$