Fluid Mechanics

Demos

"Fluid" = anything that flows
- liquids = incompressible (almost) \( p = \text{const} \)
- gases = compressible
- plasmas = compressible/incompressible
- human crowds = compressible to a limit
- traffic = compressible to a limit

2B20.60
- lateral
- hydrostatic
- pressure = human crowds - compressible to a limit
- pressure = traffic - compressible to a limit

Pascal's Vases

Mass density plays role of mass \( p = \frac{\text{mass}}{\text{volume}} \)

Note: water is dense 1 kg/l
- a gallon weighs 8 lbs

Pressure = analog of force in fluids

\[ p = \frac{\text{force}}{\text{area}} \left( \frac{\text{N}}{\text{m}^2} = \text{Pa} \right) \]

2B30.30
- Magdeburg Hemispheres
- pressure exists everywhere in a fluid
- \( p(x,y,z) \)

2B40.10
- weigh submerged block

2B40.42
- buoyancy
- Balloon

Glass bubble empty inside
Hydrostatic Pressure

Due to weight of fluid above

Look at column of fluid

Depth $d$, area $A$

Volume $= Ad$

Mass $= pAd$ ($p =$ const)

$\Rightarrow$ weight $= pAdg$

Column is held up by $p$ at bottom

$\Rightarrow$ $F = pA = pAdg + pA$

$\Rightarrow$ $p = pg + p_A$

"Gauge Pressure" $p_g = p - p_A$ (since gauge reads zero at atmospheric press.)

$[p_g = p - p_A = pg]$ Depends only on depth!

How deep in water does $p_g = 1 \text{ atm} = p_A$?

$$d = \frac{p_A}{\rho g} = \frac{10^5 \text{ Pa}}{10^3 \text{ kg/m}^3 \cdot 10 \text{ m/s}^2} = 10 \text{ m}$$

$=$ $p_g 10^3 \text{ kg/m}^3 10^2 \text{ m/s}^2$ $=$

Familiar to scuba divers
What causes atmospheric pressure?

- weight of air column
- but that depends on...
- kinetic energy of air molecules

\[ p_A \text{ varies with temperature, altitude, other weather factors} \]

@ Sea level: \( p_A = 1 \text{ atm} = 1 \times 10^5 \text{ Pa} = 14.7 \text{ psi} \)

@ Denver: \( p_A = 0.8 \text{ atm} = 8 \times 10^4 \text{ Pa} = 12.1 \text{ psi} \)

Range at sea level: 15.6 psi to 12.5 psi

- 1.06 atm to 0.85 atm

- 20% max variation

- Normal weather: \( \pm 5\% \)

Hydraulic lift: uses volume for mechanical advantage

\[
\begin{align*}
\frac{p_1}{A_1} &= \frac{p_2}{A_2} \\
\Rightarrow F_2 &= F_1 \frac{A_2}{A_1}
\end{align*}
\]

area multiplier
Buoyancy: Due to depth variation of pressure

Not just floating objects, anything!

\[ F_1 = \rho_1 A = \rho g d_1 A + \rho_A A \]
\[ F_2 = \rho_2 A = \rho g d_2 A + \rho_A A d_1 \]
\[ F_2 - F_1 = \rho g A (d_2 - d_1) \]
\[ \text{volume } V! \]

\[ F_2 - F_1 = F_B = \rho g V = \text{weight of water displaced!} \]

\[ \Rightarrow F_B = \text{weight of fluid displaced} \]

Archimedes’ Principle

Float if \( F_B = \) \( mg \) then object not fully submerged

ICE: How much below surface?

\[ M_i = \rho_i V \Rightarrow m_i g = \rho_i V = F_B = \rho_w V_{\text{below}} \]

\[ \Rightarrow V_{\text{below}} = \frac{\rho_i}{\rho_w} = \frac{0.9167 \text{ g/cm}^3}{1.0000 \text{ g/cm}^3} = 0.9167 \]

\[ \Rightarrow \frac{V_{\text{below}}}{V} = \frac{\rho_i}{\rho_w} = \frac{0.9167}{1.0000} = 0.9167 \]

\[ \Rightarrow \text{only } \frac{1}{12} \text{ of ice is above water!} \]

(1/10 in saltwater)