Fluids

Phases:
- gas
- liquid
- space
- plasma

Plasma:
- ions flying around
- high temp high pressure
- used in fusion

Density/Specific Gravity ($\rho = \frac{m}{V}$)

$\rho_{H_2O} = \frac{1.0\text{g}}{\text{cm}^3} = \frac{10^3\text{kg}}{\text{m}^3} = \frac{1\text{kg}}{\text{L}}$

$\rho = \frac{m}{V}$, unit: $\text{kg/m}^3$

Find mass of iron ball $w/r = 18\text{cm}$,

$F = 7.8 \cdot 10\text{kg/m}^3 \cdot \frac{4}{3}\pi (r^3) = \frac{4}{3}\pi (18\text{cm})^3$

$M = \rho V = \frac{(7.8 \cdot 10\text{kg/m}^3) \cdot 4\pi (18\text{cm})^3}{3}$

$M = 1.9\text{kg}$

Specific Gravity: ratio of density of object to density of $H_2O$

S.G. = $\frac{\rho_{\text{object}}}{\rho_{H_2O}}$

Pressure:

$P = \frac{\text{Force}}{\text{Area}}$, unit: $\frac{\text{N}}{\text{m}^2} = 1\text{ Pa (Pascal)}$

$m = 60\text{kg}$

$A = 600\text{m}^2$

$10^4\text{cm}^2 = 1\text{m}^2$

$P = \frac{F}{A} = \frac{60\text{kg} \cdot 9.8\text{m/s}^2 \cdot 10^4\text{cm}^3}{600\text{cm}^2 \cdot 1\text{m}^2} = 1.2 \cdot 10^4\text{N/m}^2$
Pressure on a Fluid

- Pressure = the particles pushing on the object
- Pressure is equal in all directions at any given level
- Pressure is greater at the bottom level than on the top level

Example:

\[ P = \frac{F}{A} = \frac{h \cdot F}{A} = \rho g h \]

\[ P_{\text{fluid}} = \rho g h \]

\[ P = P_o + \rho g h \]

\[ P_o = 1.0 \times 10^5 \text{ N/m}^2 = 10^5 \text{ Pa} \]

\[ \rho_{\text{water}} = 10^3 \text{ kg/m}^3 \text{ (}4^\circ \text{C)} \]

\[ 101.3 \text{ kPa} = 10^5 \]

\[ \Delta P = \rho g h = \frac{10^3 \text{ kg/m}^3 \times (9.8 \text{ m/s}^2) (30 \text{ m})}{\text{m}^2} = 30 \times 10^5 \text{ Pa} \]

Atmospheric Pressure:

- 1 Atmosphere = 101.3 kPa = 10^5 Pa = 10^5 N/m^2 = 1 Bar

Gauge Pressure: \( P_g \)

\[ P_{\text{total}} = P_o + P_g \]

Example:

\[ \Delta P = \frac{F}{A} \]

\[ F = P \cdot A = (10^5 \text{ N/m}^2)(1.4 \text{ m}) (2.9) \]

\[ F_{\text{total}} = 4.6 \times 10^6 \]
Fluids in Motion

*Viscosity* ~ liquid friction

- Streamline/Laminar flow
- Turbulent flow

\[
\text{mass flow rate } = \frac{\Delta m}{\Delta t} = \text{constant}
\]

\[
\frac{\Delta m}{\Delta t} = \frac{pV_1}{\rho} = \frac{pV_2}{\rho}
\]

\[
\text{Continuity Equation: } A_1V_1 = A_2V_2
\]

HVAC: Heating, Ventilation, Air Conditioning

3 changes/hour

\[
V_{al} = 233 m^3
\]

\[
A_V = \frac{A_{al}V_{al}}{\Delta t} = \frac{233 m^3}{1200 s} = (1.0 m \times 0.3 m) \times V_1,
\]

\[
V_1 = \frac{233 m^3}{1200 s \times 0.3 m^2} = \frac{0.65 m/s}{0.3 m}
\]

Cubic Feet per Minute: CFM

\[
\frac{\Delta V}{\Delta t} = \frac{233 m^3}{20 \text{ min} \times (3.28 ft)^3}
\]

Moving air has lower pressure than stationary air.

Bernoulli's Equation:

\[
W_1 = F_1 \cdot \Delta l = P_1 \cdot A_1 \cdot \Delta l
\]

\[
W_2 = -P_2 \cdot A_2 \cdot \Delta l_2
\]

\[
W_3 = -mg (y_2 - y_1) \text{ (by gravity)}
\]

\[
W_{tot} = W_1 + W_2 + W_3 = \Delta KE
\]

\[
= P_1 A_1 \Delta l - P_2 A_2 \Delta l_2 - mg y_2 + mg y_1
\]

\[
= \frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2
\]

\[
= \frac{1}{2} (\Delta l (p_0) v_0^2 - \frac{1}{2} (\Delta l (p_2) v_2^2)
\]

\[
p_1 + \frac{1}{2} p v_1^2 + p g y_1 = p_2 + \frac{1}{2} p v_2^2 + p g y_2
\]
Example: 41

\[ P_0 = 24.0 \text{kPa} \]
\[ P_1 = 32.0 \text{kPa} \]
\[ \Delta V_0 / \Delta t = ? \]
\[ \Delta t \]
\[ A_1 = 11 \text{ } \text{m}^2 \]
\[ y_1 = y_2 \]
\[ A_2 = 11.2 \text{ } \text{m}^2 \]
\[ \rho = 1000 \text{ } \text{kg/m}^3 \]
\[ \rho = 32.0 \text{ } \text{kPa} \]
\[ P_1 = 32.0 \text{ } \text{kPa} \]
\[ P_2 = 24.0 \text{ } \text{kPa} \]
\[ \rho = 1000 \text{ } \text{kg/m}^3 \]
\[ P_1 = P_2 + \frac{1}{2} \rho v_1^2 + \rho g y_1 \]
\[ P_2 + \frac{1}{2} \rho v_2^2 \]
\[ V_1 A_1 = V_2 A_2 \]
\[ V_1 = \frac{q}{A} \]
\[ v_2 = \frac{q}{A} \]
\[ P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2 \]
\[ P_1 + \frac{1}{2} \rho v_1^2 = P_2 + \frac{1}{2} \rho \frac{81}{16} v_1^2 \]
\[ \rho \frac{81}{16} v_1^2 \]
\[ P_1 - P_2 = \frac{1}{2} \rho v_1^2 \left( \frac{81}{16} \right) \frac{16}{16} = \frac{65}{32} \rho v_1^2 \]
\[ \frac{A \Delta l}{A} = \frac{32}{13} \left( \frac{3.2 \cdot 10^4 \text{Pa} - 2.4 \cdot 10^4 \text{Pa} \cdot 10^3 \text{kg/m}^3 \cdot 0.03 \text{m}^2 \cdot 1 \text{m} \right) = 5.4 \text{ m}^3 / \text{s} \]

Example: 43

\[ F_2 = P_2 A \]
\[ A = 240 \text{ m}^2 \]
\[ P_1 + \frac{1}{2} \rho v_1^2 = P_2 \]
\[ F_{\text{net}} = (P_2 - P_1) A = A \frac{1}{2} \rho v_1^2 \]
\[ = (240 \text{ m}^2 \cdot 1.2 \text{ kg/m}^3 \cdot 35 \text{ m/s}) \]
\[ = 0 \]
Bernoulli’s Equation: Luigi Problems

44. What is the lift (in newtons) due to Bernoulli’s principle on a wing of area 78 m\(^2\) if the air passes over the top and bottom surfaces at speeds of 260 m/s and 150 m/s, respectively?

\[
P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2 \quad y_1 = y_2
\]

\[
F = PA \quad F_{\text{net}} = (P_1 - P_2)A = \frac{1}{2} \rho v^2
\]

\[
(P_1 - P_2)(A) = \frac{1}{2} \rho (v_2^2 - v_1^2)(A)
\]

\[
F = \frac{1}{2} (1.29 \text{ kg/m}^3)(260 \text{ m/s})^2(150 \text{ m/s})^2(78 \text{ m}^2) = 2.3 \times 10^5 \text{ N}
\]

46. Water at gauge pressure of 3.8 atm at street level flows into an office building at a speed of 1.6 m/s through a pipe 5.0 cm in diameter. The pipe tapers down to 2.6 cm in diameter by the top floor, 18 m above, where the faucet has been left open. Calculate the flow velocity and the gauge pressure in such a pipe on the top floor.

\[
y_1 = 0
\]

\[
P_1 = 3.8 \text{ atm} \quad P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2
\]

\[
v_1 = 1.6 \text{ m/s}
\]

\[
l_1 = 5.0 \text{ cm}
\]

\[
l_2 = 2.6 \text{ cm}
\]

\[
y_2 = 18 \text{ m}
\]

\[
V_2 = \frac{A_1 V_1}{A_2} = \frac{0.60 \text{ m}^3(5.0 \times 10^{-2} \text{ m}^2)}{2.6 \times 10^{-2} \text{ m}^2} = 2.2 \text{ m/s}
\]

\[
V_2 = (3.8 \text{ atm}) \frac{1 \text{ atm}}{1.013 \times 10^5 \text{ Pa}} = \frac{1}{2} (1000 \text{ kg/m}^3)(1.6 \text{ m/s})^2(2.2 \text{ m/s})^2
\]

\[
= (1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(-18) = 2.0 \times 10^5 \text{ Pa} \quad \frac{1}{1.013 \times 10^5 \text{ Pa}} = 2.0 \text{ atm}
\]

\[
P_2 = 2.0 \text{ atm}
\]