Ch 14. Fluid Mechanics
### 14-1. Density

**Density** \[ \rho = \frac{m}{V} \quad \text{kg/m}^3 \]

1 g/cm\(^3\) = 1000 kg/m\(^3\)

*Intrinsic to a material, independent of size & shape*

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>DENSITY (kg/m(^3))*</th>
<th>MATERIAL</th>
<th>DENSITY (kg/m(^3))*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air (1 atm, 20° C)</td>
<td>1.20</td>
<td>Iron, steel</td>
<td>7.8 \times 10^3</td>
</tr>
<tr>
<td>Ethanol</td>
<td>0.81 \times 10^3</td>
<td>Brass</td>
<td>8.6 \times 10^3</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.90 \times 10^3</td>
<td>Copper</td>
<td>8.9 \times 10^3</td>
</tr>
<tr>
<td>Ice</td>
<td>0.92 \times 10^3</td>
<td>Silver</td>
<td>10.5 \times 10^3</td>
</tr>
<tr>
<td>Water</td>
<td>1.00 \times 10^3</td>
<td>Lead</td>
<td>11.3 \times 10^3</td>
</tr>
<tr>
<td>Seawater</td>
<td>1.03 \times 10^3</td>
<td>Mercury</td>
<td>13.6 \times 10^3</td>
</tr>
<tr>
<td>Blood</td>
<td>1.06 \times 10^3</td>
<td>Gold</td>
<td>19.3 \times 10^3</td>
</tr>
<tr>
<td>Glycerin</td>
<td>1.26 \times 10^3</td>
<td>Platinum</td>
<td>21.4 \times 10^3</td>
</tr>
<tr>
<td>Concrete</td>
<td>2 \times 10^3</td>
<td>White dwarf star</td>
<td>(10^{10})</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.7 \times 10^3</td>
<td>Neutron star</td>
<td>(10^{18})</td>
</tr>
</tbody>
</table>

*To obtain the densities in grams per cubic centimeter, simply divide by 10\(^3\).*

**Specific gravity** \[ \frac{\rho}{\rho_{\text{water}}} \]
14-2. Pressure in a Fluid

Pressure in a fluid of uniform density (Static Case)

\[ p_2 - p_1 = -\rho g (y_2 - y_1) \]
\[ p = p_0 + \rho gh \]

Pressure is the same for any 2 points at the same level in the fluid.

Gauge pressure:
Excess pressure above atmospheric pressure
Pascal’s Law

Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the container.

Application in hydraulic lift

\[ p = \frac{F_1}{A_1} = \frac{F_2}{A_2} \]

\[ F_2 = \frac{A_2}{A_1} F_1 \]
14-3. Buoyancy

Archimedes’ Principle:
When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

\[ B = \rho_{\text{fluid}} g V_{\text{displaced fluid}} \]
Surface Tension

Liquid alone tends to minimize its surface area

Liquid in contact with solid

Wetting

Non-wetting

Gas-liquid interface

SOLID

GAS

LIQUID

Water: $\theta < 90^\circ$

Mercury: $\theta > 90^\circ$

Capillarity

Wetting

Non-wetting
14-4. Fluid Flow

Ideal fluid: incompressible (ρ const.) & no internal friction (viscosity)

Laminar flow:
- adjacent layers of fluid slide smoothly & flow steadily

Turbulent flow:
- irregular & chaotic flow
- no steady-state pattern

**Denser streamlines, higher speed**

**Continuity Equation**

Incompressible fluid:

\[
dm_1 = dm_2 \quad (\rho A_1 v_1 dt = \rho A_2 v_2 dt)
\]

\[
A_1 v_1 = A_2 v_2
\]

Volume flow rate: \( dV/dt = Av \)
14-5. Bernoulli’s Equation

For incompressible, steady flow of a fluid with no viscosity

\[ p_1 + \rho g y_1 + \frac{1}{2} \rho v_1^2 = p_2 + \rho g y_2 + \frac{1}{2} \rho v_2^2 \]

Links pressure $p$, height $y$, flow speed $v$


Special Cases of Bernoulli’s Equation

Special case #1:

\[ p_1 = p_2 \]

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

Torricelli’s theorem:

\[ v_1 = \sqrt{2g(y_2 - y_1)} \]

Special case #2:

Same height:

\[ p_1 + \frac{1}{2} \rho v_1^2 = p_2 + \frac{1}{2} \rho v_2^2 \]

Where the speed is high, the pressure is low.
Applications of Bernoulli’s Principle

Dec. 17, 1903: First flights by Wright brothers.