Fluid Dynamics

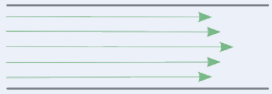
Viscosity (η)

- the resistance of a fluid
- ↓ viscosity = ↓ internal resistance to flow; ideal fluid behavior
- assumed negligible (unless indicated otherwise); conservation of energy in low-viscosity fluids
- Viscous drag = non-conservative force when η = 0, fluid is inviscid

SI unit: pascal-second

$$Pa \cdot s = \frac{N \cdot s}{m^2}$$

Laminar flow



- smooth, parallel movement of fluid
- interior layers of fluid move faster than layers closest to pipe

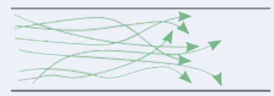
Poiseuille's Law:
used to find **flow rate (Q)**

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

(do not need to memorize this equation - only relationship)

⇒ assuming *constant flow rate*, radius (**r**) is inversely exponentially related to pressure gradient (ΔP)

Turbulent flow



- rough, disorderly
- **eddies** – swirls of fluid forming downstream of an obstruction.
- can occur when fluid speed exceeds **critical speed (v_c)**

$$v_c = \frac{N_R \eta}{\rho D}$$

Linear Speed

- measure of linear displacement in a given time.
- **flow rate, Q** (volume/time) = constant in closed system

Continuity Equation:

$$Q = v_1 A_1 = v_2 A_2$$

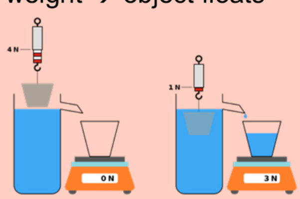
↓ Area (A) = ↑ linear speed of fluid (v)

- statement of conservation of mass

Archimedes' Principle

$$F_{buoy} = \rho_{fluid} g V_{submerged}$$

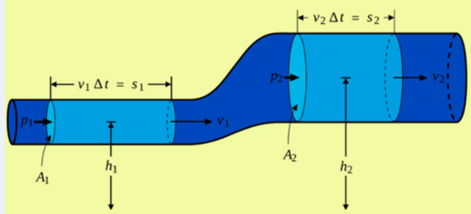
- Buoyant force equal to weight of displaced fluid.
  - ⇒ weight of fluid displaced **<** object weight → object sinks
  - ⇒ weight of fluid displaced **≥** object weight → object floats



Bernoulli's Equation

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

https://images.app.goo.gl/R2psuR8u8hVBMABv9



- P = Absolute pressure in fluid below the surface:

$$P = P_o + \rho g z$$

- **Dynamic pressure = flow rate** (q/Q)

$$Q = (1/2)\,\rho v^2$$

- **Static pressure** = $P + \rho g h$

Used for:
Pitot Tubes
Venturi Effect: explains changes in *fluid velocity* relative to area.

High area (low speed, high pressure)

low area (high speed, low pressure)

→ relating this to pressure gives **Bernoulli's principle**.

Related Equations:

Density (ρ) = $\frac{m}{V}$ SI unit: $\frac{kg}{m3}$

Specific gravity = $\frac{\rho_{substance}}{\rho_{water}}$

[ρ_{water} = 103 kg/m3]

Pressure:
P = $\frac{Force}{Area}$ SI unit: pascal $\frac{N}{m2}$

- For static fluids of uniform density in sealed vessel:

$$P = \rho g z$$

Gauge pressure:

$$P_{gauge} = P_{absolute} - P_{atm}$$

- Measures pressure of object relative to atmospheric pressure.