Fluids

Characteristics of Fluids and Solids

- Fluids are able to conform to shape and flow
- Solids are rigid and do not flow. Exert tangential shear forces

Density

- $\rho = \frac{m}{V}$ Water has a density of of 1 g/cm^3=1000 kg/m^3 $Weight = F_G = \rho V\mathbf{g}$
- The **Specific gravity** is when density of fluid is compared to that of pure water at 1 atm and 4 degrees Celsius. $SG = \frac{\rho}{1\frac{\text{g}}{\text{cm}^3}}$

Pressure

- $1.013x10^5\text{Pa} = 760\ \text{mmHg} = 760\ \text{torr} = 1\ \text{atm}$
- Atmospheric Pressure: changes with altitude
- Absolute (hydrostatic) Pressure: total pressure that is exerted on an object that is submerged in a fluid (both gases and liquids).

$$P = P_0 + \rho g z$$

- P is the absolute pressure P_0 is the ambient pressure, Z is positive downward.
- Gauge Pressure: $P_{gauge} = P - P_{atm}$

Hydrostatics

Study of fluids at rest and the forces and pressures associated with standing fluids.

- Pascal's Principle: Incompressible fluids transmit pressure equally to all portions of the fluid.
    - Hydraulic Systems: $F_2 = F_1(\frac{A_2}{A_1})$
- Archimedes' Principle: a body wholly or partially immersed in a fluid will be buoyed upwards by a force equal to the weight of the fluid that is displaced, **buoyancy**.

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

- Objects that float have a density less than the fluid and the buoyancy force is equal to the weight of the water.
- The amount of volume submerged of a substance is equal to the specific gravity expressed in percentage. E.g – S.G of ice =0.92 so 92% of ice is submerged in water and 8% at surface.

Molecular Forces in Liquids

- Surface Tension is a strong but thin layer of "skin" at the liquids surface, which is caused by **cohesion**. This is the pulling of the liquid inwards at the surface.
- Cohesion is the attractive force that a molecule of liquid feels toward other molecules of the same liquid.
- Adhesion is the attractive force that molecule of liquid feels towards the molecules of other substances.
    - E.g. – forms droplets on windshield, forms **meniscus** (when cohesion>adhesion then there is a convex meniscus; when adhesion>cohesion then there is a concave meniscus)

Fluid Dynamics

- Viscosity: Resistance of a fluid. Increased viscosity of a fluid increases its **viscous drag**
  - Lower viscosity fluids are said to behave more like ideal fluids which have no viscosity (**inviscid**).
  - Units of pascal-second [Pa x s = Ns/m^2]
- Laminar Flow: Smooth and orderly and is modeled as layers of fluid that flow parallel to each other
- Poiseuille's Law: for laminar flow through a pipe $Q = {\pi r^4 \Delta P}/{8\eta L}$
- Turbulence & Speed: turbulent flow is rough and disorderly and causes the formation of **eddies** which are swirls of fluid of varying sizes occurring typically on the down-stream side of an obstacle.
  - Occurs after a critical speed is reached. Once reached, laminar flow only occurs in a thin layer of fluid close to the wall called the **boundary layer**.

$$V_c = \frac{Re\ \eta}{\rho D}$$

- Steamlines: indicate the pathways followed by tiny fluid elements as they move. Velocity vector of a fluid particle will always be tangential to the streamline at any point.
  - Flow rate must stay constant in a closed system

$$Q = v_1 A_1 = v_2 A_2 \ known\ as\ the\ continuity\ equation$$

- Bernoulli's Equation: combines principles of conservation of mass and laminar/ inviscid flow: P is the absolute pressure and v is the linear speed, h is the height of the fluid above datum.

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

- Dynamic Pressure is the pressure associated with the movement of a fluid ($\frac{1}{2}\rho v_1^2$). This is the kinetic energy divided by volume.
- Pressure can be thought of as **energy density**
- Static pressure is the P+ $\rho g h_1$ term

Fluids in Physiology

- Circulatory System is a **closed loop** that has a non-constant flow rate. This flow rate is measured as a **pulse**
  - As blood flows away from the heart, each vessel has a progressively higher resistance until the capillaries, but total resistance of system decreases since the vessels are in parallel with each other.
- Respiratory System is much the same as the circulatory system.