Fluid Properties and the Conservation of Mass

Lab Lecture the week of Sep 21
Lab held in Marston 10 the week of Sep 28

In-Lab Rules

- Must wear :
  - Personal Protective Equipment: lab coat, gloves, goggles
  - Closed-toed shoes and pants
- Label all vessels (beakers, test tubes, flasks):
  - Contents, date, initials, class
  - When in doubt, label!
- No food or drink in the lab
- Safety first
  - Handle chemicals with care, always clean broken glass, don't put flammables in close proximity to flame

Fluid Properties

1. Density of a substance: the quantity of matter contained in a unit volume of the substance
   - Mass density $\rho(kg/m^3)=m/V$
   - Specific weight $\omega(N/m^3)=\rho g$
   - Relative density $\sigma=\rho_s/\rho_{H20}$

2. Viscosity: property of fluid, due to cohesion and interaction between molecules, which offers resistance to deformation.
   - Dynamic viscosity μ
   - Kinematic viscosity ν

Reynold's Number

- Ratio of the inertial forces (**$\rho v^2/L$**) to viscous forces (**$\mu v / L^2$**) .
- $Re=\rho vL/\mu=vL/\upsilon=vD/\upsilon$
- $v=\mu/\rho$
- μ is the dynamic viscosity of the fluid (kg/(m.s)), v is the maximum velocity of an object relative to a fluid (m/s) or mean fluid velocity, L is the traveled length of the fluid (m) (the symbol D is used sometimes instead of L as the hydraulic diameter), and υ is kinematic viscosity (m^2/s).

Conservation of Mass

- Antoine Lavoisier's Law (1789): mass is neither created nor destroyed: $m_{in}=m_{out}$

$$m_{in} = \rho \times Q_{in}(t) \times t_{fill}$$

$$m_{out} = \rho \times \int_0^t Q_{out}(t)dt = \rho \times \int_0^t A \times \frac{d\zeta(t)}{dt} \times dt$$

Therefore,

$$\rho \times Q_{in}(t) \times t_{fill} = \rho \times \int_0^t Q_{out}(t)dt = \rho \times \int_0^t A \times \frac{d\zeta(t)}{dt} \times dt$$

For the discontinuous condition,

$$\rho \times Q_{in}(t) \times t_{fill} = \rho \times \sum_0^t Q_{out}(t)\Delta t = \rho \times \sum_0^t A \times \frac{\Delta\zeta(t)}{\Delta t} \times \Delta t$$

Objectives

- Measure the density of water
- Check fluid velocity using Reynold's number criterion
- Estimate terms in conservation of water mass equation

Part 1 – Calculating density

- Weigh 250-mL volume of water
- Measure the water temperature
- Calculate density

Part 2 – Calculating the cross-sectional area of the tube

- Measure the length of a given flexible tubing
- Fill the tube with water
- Measure the volume of water in the tube
- Record the water temperature
- Use $V = \pi D^2/4$ (where D is the internal diameter of the tube) to calculate D
- Find the cross-sectional area of the tube

Part 3 – Calculating the velocity of a slow jet

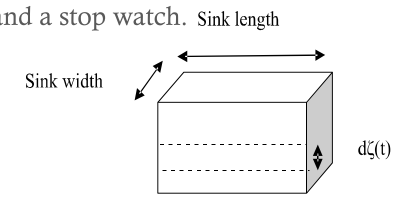
- Measure the time required by a **slow jet** of water from the faucet to fill a 250-mL graduated cylinder
- Repeat 3 times
- Calculate the flow rate of the slow jet $Q=V/t$
- Calculate the velocity of the slow jet: $v=Q/A$
- Calculate $= vD/\nu$

Part 4 – Calculating the velocity of a fast jet

- Measure the time required by a **slow jet** of water from the faucet to fill a 250-mL graduated cylinder
- Repeat 3 times
- Calculate the flow rate of the slow jet $Q=V/t$
- Calculate the velocity of the slow jet: $v=Q/A$
- Calculate $= vD/\nu$

Part 5:Conservation of mass equation

- Calculate the horizontal cross-sectional area of the sink
- Measure the time required for the free surface in the sink to rise 17 cm. Use a stopwatch and scale.
- Calculate Q_{in}
- Observe the time required to drop each centimeter until the sink fully drains. Use a measuring stick and a stop watch.
- Calculate Q_{out}



Control volume of sink