Physic 231 Lecture 22

- Main points of last lecture:
  - Tensile stress: $F/A$
  - Tensile strain: $\Delta L/L$
  - Relation between stress and strain:
    $$\frac{\Delta F}{A} = Y \frac{\Delta L}{L}$$
    $$\frac{\Delta F}{A} = \Delta P = B \frac{\Delta V}{V}$$
  - Pressure in fluids:
    $$P = \frac{F}{A}$$
    $$P_{bot} = P_{top} + \rho gh$$

- Main points of today’s lecture:
  - Buoyancy:
    $$F_B = W_{displaced} = \rho_f V_{displaced} g$$
  - Bernoulli’s equation
    $$P_f + \frac{1}{2} \rho v_f^2 + \rho g y_f$$
    $$= P_0 + \frac{1}{2} \rho v_0^2 + \rho g y_0$$
  - Viscous flow
    $$F = \eta \frac{Av}{d}$$
  - Poiseuille’s law
    $$\frac{\Delta V}{\Delta t} = \frac{\pi R^4 (P_1 - P_2)}{8\eta L}$$
IT'S OK, THAT'S JUST ARCHIMEDES
Buoyancy

• Consider the small volume in the vessel at the right. If the volume is filled with the same fluid in the vessel, it will be in equilibrium. Thus:

\[ F_B - W = 0 \quad F_B = \rho_{\text{water}} V_{\text{displaced}} g \]

• Now, replace the volume of fluid with the same volume of some other material. There will still be the same buoyant force pushing up on the block of material.

• Example: A kidney weighs 5.7 N in air. If the kidney is completely submerged in water, its apparent weight is 1.6 N. Determine the specific gravity of the kidney.

(specific gravity = \( \frac{\rho_{\text{kidney}}}{\rho_{\text{water}}} \))

Apparent weight = \( W - F_B = W \left(1 - \frac{F_B}{W}\right) = W \left(1 - \frac{\rho_{\text{water}} V_{\text{kidney}} g}{\rho_{\text{kidney}} V_{\text{kidney}} g}\right) \)

Apparent weight = \( W \left(1 - \frac{\rho_{\text{water}}}{\rho_{\text{kidney}}}\right) \Rightarrow 1 - \frac{\rho_{\text{water}}}{\rho_{\text{kidney}}} = \frac{\text{Apparent weight}}{W} \)

\( \frac{\rho_{\text{water}}}{\rho_{\text{kidney}}} = 1 - \frac{\text{Apparent weight}}{W} = 1 - 1.6/5.7 = .71 \)

Specific gravity = \( \frac{\rho_{\text{kidney}}}{\rho_{\text{water}}} = 1/.71 = 1.39 \)
Example

- A block of wood floats on the surface of a lake with 60% of its volume below the surface of the water. What is the density of the wood?

\[ F_B = W \Rightarrow \rho_{\text{water}} V_{\text{displaced}} g = \rho_{\text{wood}} V_{\text{wood}} g \]
\[ \Rightarrow \rho_{\text{water}} (0.6 \cdot V_{\text{wood}} )g = \rho_{\text{wood}} V_{\text{wood}} g \]
\[ \rho_{\text{wood}} = 0.6 \cdot \rho_{\text{water}} = 600 \text{ kg} / \text{m}^3 \]
A metal block \((\rho_{\text{steel}}=7.86\times10^3 \text{ kg/m}^3)\) floats on the top of a pool of mercury \((\rho_{\text{mercury}}=1.35\times10^4 \text{ kg/m}^3)\). The fraction of the volume of the block which lies below the surface is

- a) 0.0
- b) 0.25 \[ W = F_B; \quad W = \rho_{\text{steel}} V_{\text{steel}} g; \quad F_B = \rho_{\text{mercury}} f_{\text{below}} V_{\text{steel}} g \]
- c) 0.58 \[ \Rightarrow \rho_{\text{steel}} V_{\text{steel}} g = \rho_{\text{mercury}} f_{\text{below}} V_{\text{steel}} g \Rightarrow \rho_{\text{steel}} / \rho_{\text{mercury}} = f_{\text{below}} \]
- d) 0.42 \[ 7.86\times10^3 \text{ kg} / \text{m}^3 / 1.35\times10^4 \text{ kg} / \text{m}^3 = .58 = f_{\text{below}} \]
- e) 0.75
Does the water level go up or down?

- a) The water level goes up.
- b) The water level goes down.
- c) The water level goes neither up nor down.
A 200-ton ship enters the lock of a canal. The fit between the sides of the lock and the ship is tight so that the weight of the water left in the lock after it closes is much less than 200 tons. Can the ship still float if the quantity of water left in the lock is much less than the ship’s weight?

- a) Yes, as long as the water gets up to the ship’s waterline.
- b) No, the ship touches bottom because it weighs more than the water in the lock.
Conceptual question

A lead weight is fastened on top of a large solid piece of Styrofoam that floats in a container of water. Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down so that the weight is now suspended underneath it,

- a) the arrangement sinks.
- b) the water line is below the top surface of the Styrofoam.
- c) the water line is still flush with the top surface of the Styrofoam.
Conceptual quiz

• A lead weight is fastened to a large solid piece of Styrofoam that floats in a container of water. Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down, so that the weight is now suspended underneath it, the water level in the container
  – a) rises.
  – b) drops.
  – c) remains the same.