Test #8 – Fluid Mechanics

1) What is the buoyant force of a fully submerged beach ball with a 0.25 m radius in a swimming pool?

\[ F_B = \rho V g = \frac{4}{3} \pi r^3 g \]
\[ = (1000 \text{ kg/m}^3) \frac{4}{3} \pi (0.25 \text{ m})^3 (9.8 \text{ m/s}^2) \]
\[ = 641 \text{ N} \]

2) How much harder is it to snorkle in the Dead Sea than in a pool (compare the bouyant force)? Assume the volume of the human body is 0.08 m\(^3\) (\(\rho_{\text{Dead Sea}} = 1170 \text{ kg/m}^3\))

\[ F_{B_{\text{pool}}} = \rho_{\text{pool}} V g = (1000 \text{ kg/m}^3) (0.08 \text{ m}^3) (9.8 \text{ m/s}^2) = 784 \text{ N} \]
\[ F_{B_{\text{dead sea}}} = \rho_{\text{dead sea}} V g = (1170 \text{ kg/m}^3) (0.08 \text{ m}^3) (9.8 \text{ m/s}^2) = 917 \text{ N} \]
\[ \text{...about 130% more bouyancy (133 N)} \]

3) A 650 kg weather balloon is designed to lift a 4600 kg package. What minimum volume should the balloon have after being inflated with helium (\(\rho_{\text{helium}} = 0.18 \text{ kg/m}^3\))?

\[ F_B = F_g \]
\[ \rho_{\text{air}} V g = m_{\text{total}} g = (m_{\text{balloon}} + m_{\text{cargo}}) g \]
\[ V = \frac{m_{\text{balloon}} + m_{\text{cargo}}}{\rho_{\text{air}}} = \frac{5250 \text{ kg}}{1.29 \text{ kg/m}^3} = 4070 \text{ m}^3 \]

4) A hydraulic lift is used to lift a 2000 kg car. If the applied force (\(F_1\)) is 2800 N, what is the ratio of the piston areas (\(A_2/A_1\))? (Pascal's Principle)

\[ P_1 = P_2 \]
\[ \frac{F_1}{A_1} = \frac{F_2}{A_2} \]
\[ \frac{A_2}{A_1} = \frac{F_2}{F_1} = \frac{m \cdot g}{(2000 \text{ kg})(9.8 \text{ m/s}^2)} = 7 \]

5) The Guinness Record for the deepest scuba dive is 320 m, what is the absolute pressure at such depth? (\(\rho_{\text{sea}} = 1025 \text{ kg/m}^3\))

\[ P = \rho gh + P_0 \text{ (absolute)} \]
\[ = (1025 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(320 \text{ m}) + (10^5 \text{ Pa}) \]
\[ = 32.1 \times 10^5 \text{ Pa} + 10^5 \text{ Pa} \]
\[ = 33.1 \times 10^5 \text{ Pa} \text{ (or 33 atm)} \]
Version A

6) A dam is to be constructed such that its strength is proportional to its thickness. Considering only fluid pressure, does the following design make sense? Explain.

Yes, it does make sense because pressure increases linearly with depth \((P=\varphi gh)\) and so does the design.

7) Identify the region in the following pipe with:
   a) highest flow velocity
   b) highest pressure

Use continuity: \(v_1 A_1 = v_2 A_2\)
& Bernoulli’s Principle

8) A water hose with a 2.0 cm inside diameter delivers water at 0.15 kg/s. What is the exiting velocity? What is the exiting velocity if you place your thumb at the end and cover 75% of the area?

\[
\begin{align*}
\dot{m} &= \varphi v A \\
v &= \frac{\dot{m}}{\varphi A} = \frac{m}{\varphi \pi r^2} \\
v &= \frac{0.15 \text{ kg/s}}{(1000 \text{ kg/m}^3) \pi (0.01 \text{ m})^2} = 0.48 \text{ m/s} \\
\text{\dots at 75\% covered} \quad v_2 &= \frac{m}{\varphi (\frac{1}{4} A)} = 4v_1 = 4(0.48 \text{ m/s}) = 1.87 \text{ m/s}
\end{align*}
\]

9) During a tornado, the pressure can fall 15% below the normal atmospheric pressure. Suppose that a tornado occurred outside a window that is 0.5 m high by 0.5 m wide. What net force would be exerted on the window? In what direction would the net force be?

\[
\begin{align*}
P_{\text{net}} &= \frac{F_{\text{net}}}{A} \\
F_{\text{net}} &= P_{\text{net}} A = (10^{5} \text{ Pa} - 0.85 \times 10^{5} \text{ Pa})(0.5 \times 0.5 \text{ m}) = 3750 \text{ N}
\end{align*}
\]

10) A tornado passing over a house sometimes makes the house explode from the inside out (as you saw in previous problem). Explain this phenomenon using Bernoulli’s Principle.

The high velocity of the wind during a tornado causes a lower pressure (according to Bernoulli’s Principle). Since the air is stagnant inside the house it remains at atmospheric pressure, such difference in pressure between inside/outside causes it to explode.