Spring, 2021

Physics 312: Physics of Fluids
Assignment #4

Background Reading

Friday, Mar. 5: Kundu & Cohen 1.7

Wednesday, Mar. 10: Kundu & Cohen 1.6

Informal Written Reflection

Due: Thursday, March 11 (8 am)

Same overall approach, format, and goals as before!

Formal Written Assignment

Due: Friday, March 12 (in class)

1. In class, we mentioned several historically famous observations that can be understood as simple consequences of the properties of fluids at rest. In this problem, you'll confirm this understanding...

   (a) In his groundbreaking book, *Two New Sciences*, Galileo mentioned a curious observation that suction pumps seem to be unable to raise water to heights more than roughly 10 m. Derive this number using our analysis of pressure variation in a liquid.

   (b) Next, using the fact that mercury is much denser than water, derive a typical height of the mercury column in Torricelli's barometer. This is, again, a consequence of our analysis of pressure variation in a liquid.

(c) Finally, using the well-known result that pressure drops exponentially with height in a gas, show that the drop in atmospheric pressure at the top of 50 m building would indeed be measurable using Torricelli's barometer.

(Hint: To solve these problems, you'll only need to know standard atmospheric pressure, the density of water or mercury, and the relevant formula for pressure variation in a liquid or gas...)

2. What fraction of the volume of an iceberg (density 917 kg/m^3) floating in the ocean (salt water, density 1024 kg/m^3) is submerged?

   (Hint: Use Archimedes' principle! The weight of the fluid displaced by the submerged ice must equal the total weight of the iceberg...)

3. Many fishes have an internal, gas-filled organ that is closely-related, in evolutionary terms, to our lungs. This organ, called the swim bladder, illustrates many of the principles we've been studying...

   (a) Buoyancy control is thought to be a major function of the swim bladder: by adding gas to its bladder, a fish may adjust its density. If the density of a zebrafish with its swim bladder collapsed is 1.05 g/cm^3, calculate how much volume the inflated bladder occupies when the fish is neutrally buoyant? Give your answer as a percentage of the fish's total volume.

   (b) The swim bladder has flexible walls that can expand or contract. Thus, to maintain neutral buoyancy at different depths, a fish may need to add or remove gas from its bladder. This is a simple consequence of the properties of a fluid at rest. Explain!

(c) Evolution has equipped fishes with a remarkable set of strategies for controlling gas content. Read about swim bladders online and, in a few sentences, summarize what you learned. Note that deeper-dwelling fishes with closed bladders cannot rise to the surface too quickly. Use your knowledge of fluids to explain why not.

4. How do trees move water from their roots to their leaves, which may be tens to hundreds of feet above the forest floor?!

   (a) Read through Kundu and Cohen's discussion of liquid rising in a narrow tube (pgs. 11 and 12). Then work through Kundu and Cohen, Chapter 1, Problem 1.

   (b) Tiny tubes in the xylem of trees transport water and nutrients large distances up the trunk. Calculate, using the same formulas used above, the height that water rising in a 25 μm radius tube of xylem achieves at static equilibrium

   (c) Is your answer in (b) larger or smaller than expected?... Do some reading about xylem online and, in a few sentences, summarize the actual mechanism used by trees to transport water up from the roots to their leaves.

5. Two of the most familiar examples of surface tension phenomena are bubbles and droplets and, recently, the role they play in the spread of infectious disease has attracted considerable attention in the fluid dynamics community. Using our library's subscription to the Scopus database of peer-reviewed scientific publications, find and read a highly influential paper on bubbles or droplets and summarize something you learned. Note that Scopus will let you organize your search results by date, timed cited, and so on, which can be helpful when you're looking for recent papers, popular papers, etc. To keep things simple, limit your search to articles from the following ten physics-friendly sources:

- Science
- Nature
- Nature Physics
- Physical Review Letters
- Physical Review E
- Physical Review Fluids
- Physics of Fluids
- Journal of Fluid Mechanics
- Annual Rev. of Fluid Mech.
- Review of Modern Physics

If possible, *be ready to discuss your efforts in our meeting on Thursday*! And, above all, *have fun* with your exploration!