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Aero Thermo Hydro Engineers Nuclear Application

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Fall 2018
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Lecture: 09:30~10:45, Mon & Wed, 032-108

Problem Set 2

1. Fluid Statics Fundamentals **20%**

When the fluid velocity is zero under the hydrostatic condition, the pressure variation is due only to the weight of the fluid. Consider a small wedge of fluid at rest of size Δx, Δz, Δs and depth d into the paper. There is no shear stress by definition, and pressure is assumed to be identical on each face of the tiny element.

A. Draw a diagram for equilibrium of a small fluid element at rest.
B. Show that summation of all forces must equal zero since the element is at rest.
C. Show that there is no pressure change in the horizontal direction.
D. Express the vertical change in pressure proportional to the density, gravity and depth change in the fluid, i.e. the weight of the column of the fluid above the point.
E. Prove that pressure in a static fluid is a point property in the limit as the fluid wedge shrinks to a point.

2. Tall Tube **20%**

To illustrate that pressure is not a function of container shape, consider a 4-foot length of ½ -inch clear acrylic tube held vertically with the bottom resting on the floor. Imagine a 3-foot diameter tank of the same height sitting next to the vertical tube, both filled with water.

A. Which has the highest pressure at the bottom?
B. What if the tube and tank were a mile high?
C. What if the small tube was filled with sludge?
D. If you sit at the bottom of a pool 6 feet deep does that feel any different than if you sit at the bottom of a 6-foot-deep large lake?
E. If you happen to have a rock next to you in the lake, would it make any difference?

3. Russian Dam Disaster **20%**

The Sayano-Shushenskaya dam in Siberia suffered a major malfunction in 2009, killing 76 people. The video clip https://www.youtube.com/watch?v=SWcdDwECZU0 holds a presentation that describes the disaster and surmises that a log caught in the wicket gates induced a water hammer effect and caused the extensive damage. It demonstrates some possible effects of the large pressure forces on submerged objects such as the upstream side of a dam. Discuss the Russian Disaster as quantitatively as you possibly can.

4. Interesting Hydrostatics **20%**

A hollow metal cylinder of inside diameter d_i, outside diameter d_o, and mass density ρ_m, is closed at one end by a mass-less diaphragm. The cylinder is inverted and slowly brought down to the surface of a body of water so that the air inside the cylinder is at atmospheric pressure when the open end is just sealed off by the water surface. The cylinder is then allowed to drop until it floats in an equilibrium position, guidance to prevent toppling being provided if necessary. Assume that the air temperature remains constant, so that the air pressure in the cylinder is directly proportional to the density of the air in the cylinder. Derive the relation for the ratio c/a, where a represents the total length of the cylinder, and c denotes the distance between the bottom of the cylinder and the water level therein.

5. More Interesting Hydrostatics **20%**

A. Assuming that the greatest ocean depth is 10 miles, that sea water at atmospheric pressure has a specific gravity of 1.030, and that its bulk modulus of compressibility $E = \rho dp/d\rho$ is 300,000 psi, calculate the pressure at a depth of 10 miles (a) neglecting compressibility, and (b) taking account of compressibility.
B. The average temperature of the earth's surface is expected to rise in the next century because of an enhanced greenhouse effect. When the ocean is heated, it will expand, raising the sea level. If the ocean's average depth is 3800 m and its average thermal expansion coefficient is 1.6×10^{-4} /K, calculate the rise in sea level when the ocean increases in temperature by 1 K.
C. A hot wire anemometer probe makes use of a fine tungsten wire; a diameter of 2×10^{-4} cm is not uncommon and allows rapid response as a result of a small thermal inertia. In analyzing the flow about the wire, it occurs to the engineer that the continuum approximation may not be valid. Determine the size of a particle containing 300 molecules and compare it to the diameter of the wire. Do you think it would be adequate to consider the flow over the wire to be modeled as a continuum?
D. A droplet of volume $V = 4\pi r^3/3$ and surface area $S = 4\pi r^2$ has an internal pressure $\Delta p = 2\gamma/r$ greater than the surrounding atmosphere. Show that the work $(\Delta p)\delta V$ required to increase the volume by a small increment δV is equal to the increment in surface energy $\gamma\delta A$ associated with the surface area increment δA.
E. Make up your own problem set of hydrostatics and solve.