12/1 In Class – Fluids: Pressure and Buoyancy and a couple review problems

We begin with definitions of density and pressure that work for all cases (not just fluids).

Density and Pressure

Recall from class that density, ρ, and pressure, P, are defined as:

$$\rho \equiv \frac{m}{V}$$

$$P \equiv \frac{F}{A}$$

1. A 10 cm cube of water sits on the table. How much pressure does it exert on the table? (Hint: what force will you use in the pressure equation?)

2. We discussed two "named" units of pressure in lecture: Pascals (1 Pa = 1 N/m^2) and atmospheres (1 atm = 101kPa). There is another: mm Hg, which stands for mm of Mercury. How high of a column of mercury (in mm) would it take to equal one atm of pressure (pushing down on the surface the mercury rested on)? (The density of mercury is 13.6×10^3 kg/m^3.)

Pressure as a function of depth in a fluid:

In class, we derived this expression for pressure a depth of Δh below the surface of a fluid:

$$\Delta P = \rho g \Delta h$$

Gauge pressure:

Many devices measure gauge pressure, that is, the pressure relative to atmospheric pressure.

$$P = P_0 + \rho g \Delta h$$

where P is the absolute pressure, P_0 is atmospheric pressure, and $\rho g \Delta h$ is the pressure at some depth below atmospheric pressure.

3. Calculate the pressure difference between the surface of the water and 3m deep.

4. The absolute pressure 3m under the water is the pressure you just calculated plus atmospheric pressure. Calculate this. Explain why this new calculation is the absolute pressure.

Buoyant Force

When an object is submerged (or partially submerged) in a fluid, it feels a buoyant force because of the fluid. The buoyant force is given by:

$$F_B = m_f g$$

where m_f is the mass of the fluid displaced by the object. We found this by considering the fluid to be incompressible, and the volume of the fluid displaced must be equal to the volume of the object submerged. ($V_f = V_o$).

5. A 1kg block of gold is suspended by a force sensor. In air, the force sensor reads 9.8N. The density of gold is 19.3×10^3kg/m^3.

   (a) What is the buoyant force on the gold block if it is suspended in water?

      i. Hint: first find the volume of the gold block.

      ii. That volume is the volume of fluid displaced. Now you can find the buoyant force.

   (b) What is the new reading on the force sensor? (When the block is completely underwater?)

6. There's a famous myth that Archimedes used the idea of the buoyant force to determine if a crown was truly solid gold. You can do this by determining the density of the metal given the two weights. For example, let's say the crown weighed 20.00N in the air and 18.24N when suspended in water. What is the density of the material? Is it gold?

Review Problems

7. Shown below is a problem I found on the MIT open courseware site.[1] Try it :) If you want numbers, feel free to use d=39.2m. (A bit large, but it makes for a nice round number in the calculations.)

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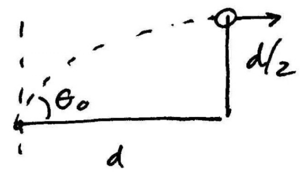
[1]Lewin, Walter, Peter Dourmashkin, Thomas Greytak, Craig Watkins, Andy Neely, Sahana Murthy, J. Litster, and Matthew Strafuss. 8.01SC Physics I: Classical Mechanics, Fall 2010. (MIT OpenCourseWare: Massachusetts Institute of Technology), http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010 (Accessed 3 Dec, 2014). License: Creative Commons BY-NC-SA

Problem 6:

A person is a playing a game that requires throwing an object onto a ledge. The ledge is a distance d and a height $d/2$ above the release point. You may neglect air resistance. You may use g for the magnitude of the gravitational acceleration.

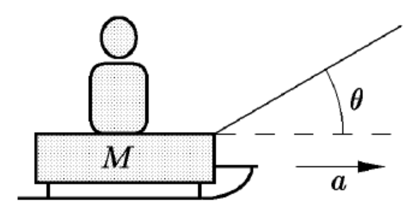


(a) At what angle must the person throw the object and with what magnitude of the velocity if the object is to be exactly at the top of its flight when it reaches the ledge? Briefly describe how you will model this problem and your strategy for finding the answer. Express your answer in terms of the given quantities d and g, as needed.

8. For this one, if you want numbers, use: $M = 25\text{kg}$, $a = 2m/s^2$, and $\theta = 60°$ If you use symbols, assume M, a, and θ are given and find T and F_N in terms of them. (Also from the MIT site[1])

Problem 2: Towing a Sled

A mother tows her daughter on a sled on level ice. The friction between the sled and the ice is negligible, and the tow rope makes an angle of θ to the horizontal. The combined mass of the sled and the child is M. The sled has an acceleration in the horizontal direction of magnitude a. As we will learn to justify in a few weeks, the child and sled can be treated in this problem as if they comprised a single particle.



a) Calculate the tension, T, in the rope and the magnitude of the normal force, N, exerted by the ice on the sled. Briefly describe how you model the problem and your strategy for solving this problem. Show all relevant free body diagrams.

9. Using what you found in the last problem, calculate the work done by each of the forces if the sled moves a distance $d = 5m$ to the right. (You may use d or numbers.)

   (a) Work done by gravity

   (b) Work done by normal force

(c) Work done by tension

(d) If the sled started from rest, what is its speed after it moves the 5m?

(e) Use kinematics and the acceleration from the last problem to check your answer.