Physics 231 – Lab 4b
Buoyancy

Equipment: shellacked wood block on string, overflow can, little beaker, big measuring cup, aluminum masses, string, force probe, string mess to hang beaker from force probe.

Objectives

This lab will cover applications of the momentum principle to:

- An object in a fluid (buoyancy)

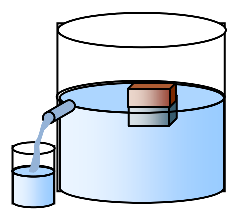
I. Buoyancy

A. Background

A concise statement of *Archimedes' Principle* is that magnitude of the (upward) buoyant force on an object is equal to the weight of the fluid that it displaces. For example, if a 50 liter drum floats in the water with 40 liters of its volume above water and 10 liters below water, then the buoyant force equals the weight of the 10 liters of water that's been displaced by the drum. Of course, if the drum is just floating, then that buoyant force must perfectly balance the weight of the whole drum.

It'll also be handy to know that the density of water is $\rho_w \equiv \frac{m_w}{V_w} = 1g/(cm^3) = 10^3 kg/m^3$.

B. Floating Object



Use the force probe to measure the following:

- The weight of the empty beaker.
- The weight of the block of wood that you will float.

To set up for the experiment:

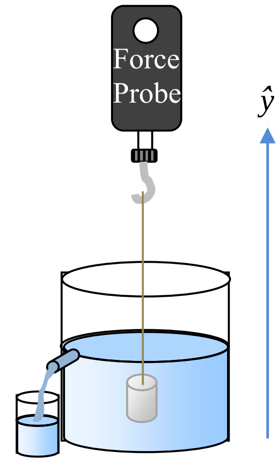
- With the beaker below the spout, fill the overflow can until a bit of water comes out. Be careful not to bump the overflow can after doing this. Now, the water remaining in the can should be on the verge of spilling out.
- Empty and dry out the beaker. Place the beaker below the spout again.

Perform the following experiment:

- *Slowly* lower the wood block into the water and catch the water that it displaces in the beaker. Be very careful that you do not splash out extra water.
- Measure the weight of the beaker and water and use that to determine the weight of the displaced water.

According to Archimedes' Principle, you should find that the weight of the water displaced is indeed equal to the weight of the floating wood (allowing for about 10% experimental error). If you find that's not the case, find and fix your mistake.

C. Submerged Object



To set up for this experiment

- Zero the force sensor with nothing touching it.
- Refill the overflow can, catching the water that spills out in the beaker.
- Empty and dry out the beaker. Place the beaker below the spout again.

Perform the following experiment:

- By hanging it from the force sensor, measure the weight of the metal object which you will submerge. Look at the readout in either the lower or upper left of the LoggerPro window on the computer (in the upper left, it will be written by the small icon that looks like the teal LabPro device.)
- *Slowly* lower the metal block into the water and catch the water that it displaces in the beaker. Be very careful that you do not splash out extra water.
- Measure the mass of the beaker and water and use that to determine the weight of the displaced water.

Analyze your results:

- On a whiteboard, draw a cartoon of the hanging / submerged mass and overlay arrows representing the *three* forces acting upon it: its weight, $\vec{w}_m = \langle 0, -w_m, 0 \rangle$, the buoyant force due to the water, $\vec{F}_w = \langle 0, w_w, 0 \rangle$ (using Archimedes' Principle to say that the magnitude of buoyancy is the weight of the water displaced), and the tension force due to the string $\vec{F}_{st} = \langle 0, F_{st}, 0 \rangle$. With its help (and knowing that the net force on the metal chunk is 0) formulate an equation for the force you'd expect the string to be exerting.
- Use Archimedes' Principle to calculate a theoretical value for the buoyant force from how much water got displaced.
- Use the force sensor to measure the force the string exerts to help hold up the object while it's fully submerged but *not* touching the bottom.

If these two values differ by much greater than 10% find and fix your mistake (it could be a calculation, or it could be a measurement.)