Prelab: Buoyancy

Everyday thing: A cargo ship, carrying thousands of tons of goods, makes it across the ocean without sinking. In the same way, us lying on a inflatable float or rowing in a canoe on Argo Pond, we don't (usually) get wet.

It is physics: buoyancy is one of the phenomena in physics with a long history of people studying it (we don't call it "Archimedes' principle" for nothing.)

Density

Reminder: if one the mass m of an object and its volume V are related by its density, usually denoted by the greek letter rho (ρ) as follows:

$$\text{(mass)} = \text{(volume)} \times \text{(density)}$$

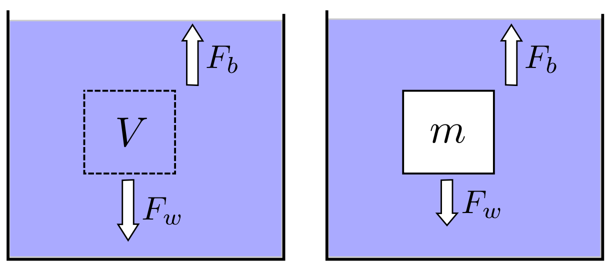
$$m = \rho V$$

This means the unit of the density is mass per unit of volume, or **kg/L** in SI units. The density of water at room temperature is close to $\rho_{\text{water}} \approx 1\,\text{kg/L}$. (This is no coincidence: the value of the kilogram was chosen specifically so that water would have a density close to 1.)

Why buoyancy must exist

The simplest way to think of buoyancy is to consider a pool of water. In our heads let's mark a region in the water of volume V (dashed box on the left panel.) The box of water we just denoted has **weight**, so it feels a gravitational force:

$$F_w = mg = \rho_{\text{water}} Vg$$



That means the water should "fall" to the ground. However, as we know, it doesn't: it is supported by the surrounding water pool. In other words, there exists an opposing force $F_b = -F_g$ created by the pool, which we call **buoyancy**.

Now let's replace the region of water by any other object of the same volume V (white box). We haven't changed the environment of that object, so the pool still exerts buoyancy on this object. The object feels a force $F_b = -\rho_{\text{water}} Vg$.

What actually happens to the object depends on the balance of buyoancy and the object's weight. Suppose the object is underwater, has an average density ρ_{object}, and thus it's weight is $F_w = \rho_{\text{object}} Vg$, the net force in the downward direction is:

$$F = F_w - F_b = (\rho_{\text{object}} - \rho_{\text{water}}) Vg \tag{1}$$

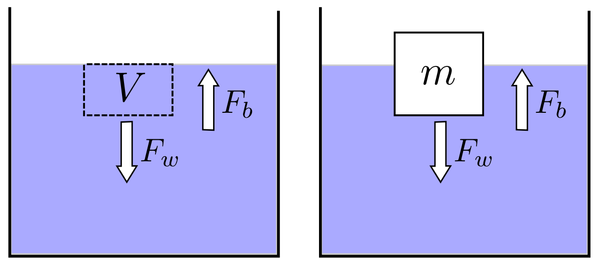
That is, buoyancy is a force strong enough to support water. If the object is denser than water, the weight overpowers buoyancy, it feels a positive force *F*, and sinks. If the object is less dense than water, the buoyancy is stronger, the force will be negative in the downwards direction, which is the same as an upward force, and the object will float.

→ http://www.youtube.com/watch?v=Lwc6QklQGFw

Another way to state the above in words is **Archimedes' principle**:

> **Buoyancy is a force on an object that is equal but opposite to the weight of the water displaced by that object**.

This also works for floating objects and it tells us how much of an object will be underwater: the object will sink until the portion that is underwater displaces exactly the amount of water whose weight is equal to the weight of the object.



In other fluids

Buyoancy is not limited to water, but exists in any fluid. Many of your favorite liquids have density close to 1 kg/L. Mercury (Hg) has density of 13.6 kg/L, so lots of objects float and displace very little of the liquid mercury. The billiard ball in the cup of mercury would sink in water but float in mercury.

→ http://www.youtube.com/watch?v=Rm5D47nG9k4

This is also the reason why it is very easy to stay afloat in the Dead Sea in Isreal. the density of humans is about 1 kg/L, comparable to that of water. Add salt to water, and you increase its density. The dead sea has a very high salt concentration, and its density is around 1.24 kg/L, which increases the buoyancy.

Play around with this simulation:
→ http://phet.colorado.edu/sims/density-and-buoyancy/density_en.html