Buoyancy

Jeremy Du, Arnold Mong

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1 Introduction

After going over basic forces, we are basically pros. Just kidding. There is much to learn. Today, we're going to talk about buoyancy. We have all (hopefully) heard of buoyancy before. If you haven't, it's probably just the word that you're unfamiliar with, and not the concept. Here's a warm-up question: Imagine a exact Styrofoam model of Arnold is in a swimming pool. Then, pretend that we also have a exact gold replica of Arnold as well. Which ones will sink, and which ones will float?

2 Density

Density and buoyancy are two concepts that are related, but not the same. In the question above, you hopefully got that one Arnold sank, and the other Arnold floated. This is because of density. Density is defined to be mass per unit volume, and is usually denoted with the Greek symbol ρ (pronounced 'row'). Since Styrofoam is less dense than water, it floats, and vice-versa with gold. However, this doesn't explain why ships can float. After all, they're made of metals, and if you have a metal bar, it would sink. ???

3 Buoyancy

In our ship dilemma, we're confused why the ship doesn't sink. However, we have to go back and remember what causes something to sink. It's what we've been talking about for the last couple of weeks: forces. When something is in water, or any fluid, there a force that opposes the gravitational force. We'll call it the buoyant force.

Archimedes, who was a Greek mathematician and physicist, made a law about buoyancy, and so it's named after him. Archimedes' Principle states: *An object that is partly or completely submerged in a fluid will experience a buoyant force equal to the weight of the fluid the object displaces.*

We can write this in math: $F_b = W_{fluid} = M_{fluid} \times g$. From our section on density, we know mass is equal to the product of volume and density, so we can write: $F_b = V_{displaced} \times \rho_{fluid} \times g$. Use this equation we just got to explain to yourself why it makes sense that something denser than the fluid it's in sinks, and less dense floats.

Now let's go back to the ship. What are the necessary conditions for a ship to float?

4 Problems

1. Arnold has a beach ball. It has a radius of 1 m, but only weighs 0.1 kg. If Arnold goes to the beach and completely submerges the beach ball into the ocean, what is the net force on the ball? Assume ocean water has a density of 1 g/mL.

2. Arnold enjoys playing basketball. Assume his basketball is a perfect sphere. The mass of the ball is 1 kg, and the radius is 0.12 m. Let's say Arnold air-balls his shot, and the ball rolls and eventually falls into a swimming pool.

   (a) What is the density of the basketball? Will it float in water? (Water has a density of 1 g/mL).

   (b) What is the buoyant force F_b?

   (c) Use Archimedes' Principle to calculate how much water the ball displaces.

   (d) What percentage of the basketball will be above the surface of the water?

3. Arnold puts a scale at the bottom of a bathtub. Then. he puts a 10 kg block of aluminum (which is really dense!) inside the bathtub, and watches the block drop onto the scale. If the density of aluminum is 2.7 kg/L (found from the Internet) and the density of water is 1 kg/L, what will the scale read?

4. Is it possible for something to be completely submerged in a fluid, but not touching the bottom? Assume no external forces are applied.

5. Arnold is on a boat in a lake. On his boat, he has an anchor, a cat, and a turtle. If he throws the anchor off the boat, will the water level rise, fall, or stay the same? What about the cat?