BID: Buoyant force / apparent weight

The Big Idea

When objects are submerged (or even partially submerged) in fluid, the pressure imbalance between the pressure at the bottom of the object (deeper and therefore under more pressure) and the top of the object creates a buoyant force. It turns out that this buoyant force is equal to the weight of the fluid displaced by the object. The "apparent weight" can be found using a free body diagram: Apparent weight is equal to the actual weight (w=mg) less the buoyant force pushing up on the object. If the object sinks to the bottom, the apparent weight would be the same as the normal force of the object.

More details

For buoyant force, the formula to use is: $F_b = \rho V g$, where ρ is the density of the fluid, ***not*** the density of the object. And V is the volume of the fluid displaced (ie the amount of the object that is submerged). When dealing with apparent weight, sometimes a free body diagram helps. The same is true with a floating object which is only partially submerged.

How to recognize it

The most common problems ask for either the buoyant force on an object or the apparent weight of an object floating in a liquid. More interesting problems involve a floating object where you're either given the density of the fluid and the object and asked to determine what percentage will be submerged or above the fluid, or the problem will give you the percent submerged or above the fluid and ask for the object's density.

How to tackle it

If the problem is to find the buoyant force, basically plug and chug. If the problem is an apparent weight problem, you have to calculate both the buoyant force and the weight of the object. If they don't give you the actual weight or mass of the object, remember you can find the mass from the density and volume relationship. For floating problems, just set weight and buoyant force equal to each other. If you're trying to find out how much of a substance is floating, just arrange your equations so that you compare the V displaced (from the buoyant force equation) and the total volume (from the weight equation). The equation, once you derive it, becomes the density of the object divided by the density of the fluid. If this is water, it's the same as the "specific gravity". This only works for objects with a density ***less*** than the fluid they're floating in.

Pitfalls to watch for

1) Be sure to use the correct density value. Often fluids problems will give both the density of the fluid and the object.
2) Be careful not to mix up mass, weight, or density in the equations.

Example problem

A tree (whose wood has a ρ of 780 kg/m^3) falls into the river. (a) Does it sink or float? Explain your answer. (b) If it sinks, what is its apparent weight. If it floats, what percentage of the wood's volume stays above water?

Solution:

a) The tree would float. Any solid object with a density greater than that of water (1000 kg/m^3) will sink. If the density of the object is less than that of water, it'll float. The wood has a density less than water, so it floats.

b) $F_b = w$

$\rho_{water} V_{disp} g = mg$

$\rho_{water} V_{disp} g = \rho_{object} V_{object} g$

$\rho_{water} V_{disp} = \rho_{object} V_{object}$

$V_{disp}/V_{object} = \rho_{object}/\rho_{water} = 0.78$ or 78% (this is the amount displaced or submerged)

% floating = 1 - % submerged = $\boxed{22\%}$