**Buoyancy**

**Background**

Every physics student should know the story of Archimedes, who solved the problem of finding out if a crown was truly made of pure gold or if it was lesser materials. Archimedes’ Principle states that the buoyant force on a body partially or fully submerged in a fluid is equal to the weight of the fluid that is displaced. In equation form, that looks like



One of the most uncertain measurements you can make in a physics lab is the volume of a fluid, due to its surface tension and the attraction/repulsion of the fluid to the container. On the other hand, mass is one of the easiest and most accurate measurements we can make given the availability of electronic scales. Therefore, today you will measure density using only an electronic scale, distilled water , and a small uniform weight of unknown density.

**Goal:** To perform your own version of Archimedes experiment and determine the density of an unknown object.

**Part I - Measuring the Buoyant Force**

* Consider the three possible scenarios described and shown in the images below. For each, draw the requested free body diagrams.
  + Scenario 1: a beaker half full of water, and a weight hanging above the water. Draw a free body diagram for the beaker and another for the weight.
  + Scenario 2: a beaker half full of water, and a weight hanging from a string down into the water (but not touching the bottom). Draw a free body diagram for the system (water, beaker, and weight).
  + Scenario 3: a beaker half full of water and a weight lying submerged on the bottom. Draw a free body for the system (water, beaker, and weight).

* Now, begin to conduct the experiments. Fill a beaker to approximately half. Measure the following masses:

mass of beaker, half full of water = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

mass of hanging weight (while it is dry) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

mass of beaker, half full of water, with weight submerged = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

mass of beaker, half full of water, weight resting on bottom = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

* Using the free body diagrams you created, determine the force of tension  on the weight when it is:

hanging in the air = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

submerged in the fluid = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

resting on the bottom of the beaker = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

(Should be zero.)

* In this case, the buoyant force is equal to the difference in the tension when it is hanging in the air and hanging in the fluid, or . Use this to calculate your buoyant force:

 = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N

**Part II - Known fluid - body of unknown density**

If a body is submerged in a fluid of known density - that is, if the buoyant force is known (or can be calculated) - the volume of the body can also be calculated using



* Using this information and the buoyant force you found above, calculate the volume of your hanging weight:

Volume of hanging weight = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m3

* Calculate the density of the hanging weight. Remember the simple definition of density, :

Density of hanging weight = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg/m3

* What metal is this weight (probably) made of? Use an Internet search to help you decide.

**Part III - Unknown fluid - body of known density**

Remember Archimedes’ Principle: the buoyant force on a body fully or partially submerged in a fluid is equal to the weight of the fluid displaced by the body:



Use this information, along with the known hanging weight from Parts I and II, to determine the density of the unknown fluid provided.

* Hang your weight and submerge the weight entirely in the unknown fluid, but do not rest it on the bottom. Measure the mass of the beaker of fluid with the weight hanging submerged. Then, rest the mass on the bottom of the container and measure the mass of the beaker with the weight resting on the bottom. Follow through with the process for determining the density of the unknown fluid.

mass of beaker, half full of water, with weight submerged = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

mass of beaker, half full of water, weight resting on bottom = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg

Density of unknown fluid = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg/m3

**Buoyancy Activity**

Let’s put the principles of buoyancy to work to calculate the buoyant force of air on your body. Yes - that exists. We don’t have a tub of water to submerge you in, so instead you’ll have to approximate your volume and use your mass.

1. First, figure out your mass. You probably already know your weight in pounds, so just do the necessary conversions to determine a mass in kilograms. (If you are uncomfortable using your own weight, it’s okay to make up a body!)
2. Now, use simple shapes to approximate your volume. For instance, if your head was approximately a sphere, and you measured the radius, you could approximate the volume of your head. You can make similar approximations for your torso, arms, and legs as cylinders or boxes. Be sure to show your work, especially with regard to the volumes of various body parts.

Volume of you \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m3

Density of you \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg/m3

1. Assume the density of air is 1.204 kg/m3 (at 20° C). What is the buoyant force of the atmosphere on you?

Fb = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ N