Lab A. Fluids

Pre-lab Assignment

1. Derive Equation 3 from equations 1 and 2.

2. Using equations 1, 2 and 4, derive equation 5.

3. Show how you would modify equation 2 to include the buoyant force due to air, since air is a fluid too. Assume that the balance itself is not affected by the air.

Lab A. Fluids

Objective

To measure the density of a solid and a liquid using Archimedes's Principle

Equipment

Overhead triple beam balance (or just a stand and force meter to hang from it)
ringstand
large beaker and beaker support
assorted known metal (copper, aluminum) samples of at least 4 different sizes and masses
monofilament line
distilled water
propanol (or other liquid of different density like rubbing alcohol)

Background

Measuring the density of an object is fundamental to many fields of science and engineering. There are many methods for measuring density, depending on the size, shape, desired accuracy, and phase of the material (i.e., gas, liquid, solid). The crudest is the hygrometer used to check the freezing point of the solution in your car's radiator. Another basic one is to directly weight the object and divide by the volume. This method is not practical for oddly shaped items.

Here, you will use a method that involves weighting a solid when it is in the air and then when it is immersed in water. This is the method Archimedes used to analyze the king's crown and to determine if it was made of solid gold or not.

Method

Archimedes's principle states that the apparent loss of weight of a body immersed in a fluid is equal to the weight of the fluid displaced by the body. If a body is completely immersed in water, then the volume of the water displaced is simply equal to the volume of the solid and we can write

$$W_w = W_a - \rho_w V g \quad (1)$$

$$\rho_s V g = W_s \quad (2)$$

where

W_a is the weight of the body in air
W_w is the weight of the body immersed in water
g is the usual gravitational acceleration
ρ_s is the density of the solid
ρ_w is the density of the water
V is the volume of the solid

Solving for ρ_s we find

$$\rho_s = \rho_w \frac{W_a}{W_a - W_w} \qquad (3)$$

You can use a similar method to find the density of an unknown liquid. Measure the weight of some solid body in air, W_a, when immersed in water, W_w, and when immersed in some unknown liquid, W_l. You can write for the weight of the object in the liquid,

$$W_l = W_a - \rho_l V g \qquad (4)$$

Using Equations 1, 2, and 4 and eliminating V and ρ_s, one gets

$$\rho_l = \rho_w \frac{W_a - W_l}{W_a - W_w} \qquad (5)$$

Procedure

ACTIVITY 1

Choose four samples of a solid material, a known metal such as copper. Tie a monofilament fishing line with a loop at the end for hanging a mass from the balance. Weigh each sample in air.

Solid 1 samples	W_a/g (kg)	W_w/g (kg)	ρ_s (kg/m^3)
1			
2			
3			
4			
Average ρ_s and standard deviation			

Then swing the beaker into place, fill the beaker with water and weigh the specimen while it is fully immersed in water. Make sure it is not touching the bottom of the beaker.

Calculate the density of the solid, enter in the table above, and show your calculations below.

ACTIVITY 2

Now choose four samples of a second solid and repeat your measurements.

Solid 2 samples	W_a/g (kg)	W_w/g (kg)	ρ_s (kg/m^3)
1			
2			
3			
4			
Average ρ_s and standard deviation			

ACTIVITY 3

Now use one of your solid materials (use all of the sample pieces) to determine the density of an unknown liquid. You already know the solid's weight in air and water. *After drying the solid carefully*, weigh it when immersed in the unknown liquid and compute the density of the liquid.

Solid _____ samples	W_a/g (kg)	W_l/g (kg)	ρ_l (kg/m^3)
1			
2			
3			
4			
Average ρ_l and standard deviation			

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Post-lab Assignment

Compare your densities to accepted values (found in the literature) and compute the percentage error, $\frac{\rho_{\text{true}} - \rho_{\text{meas}}}{\rho_{\text{true}}} \cdot 100\%$. Show your calculations. Is the percentage error within one standard deviation, based on the variation in your measurements?

Material	Measured ρ_s (kg/m^3)	Accepted ρ_s (kg/m^3)	% error