Lab 9 – Archimedes' Principle Rev Fall 2025

Abbreviated Lab Report – Instructions: your lab submission for this lab is abbreviated. It consists of an acceptable abstract, your worksheets, and a reference all combined into a single pdf. The worksheets are in pdf and odt format if you want to type in the values. Otherwise you might want to print them off to include in your report.

Your hypothesis for every part is that the buoyant force on an object is equal to the weight of the fluid displaced by that object. For the solid metal objects and the ping-pong ball, the fluid is water. For the balloon, the "fluid" is air.

For the solid objects, the criteria for validity is the %error in your measurements of densities. For the helium balloon, you will use a percent deviation between the measured lift and the lift predicted from Archimedes' principle and the ideal gas law.

You will work mostly from the worksheet. The point of these instructions is to tell you what each section is for and what results you should be able to report at the end.

First, you will create standard densities for three solid objects: two spheres and one metal cylinder. You will measure diameters (and the cylinder height) with the vernier caliper in millimeters, convert those lengths to meters, compute the volumes in cubic meters using the geometry formulas for a sphere and a cylinder, and use the electronic balance (in kilograms) to get the masses. From this you will calculate three densities in kg/m^3. These are your "standard" densities for those materials. After doing this portion of the procedure, you will not refer to these values until the end, **except that you may use the diameter of the ping-pong ball**.

Next, you will hang Sphere 1 (the metal sphere) from a spring scale in a graduated cylinder of water. You will record m_{before} and m_{after} from the spring scale, and water levels before and after removing the sphere. The change in water level gives the displaced volume; the spring scale gives you an independent mass. You will convert everything to SI units, compute the density of the sphere from this method, and compare it to your standard density by calculating a percent error.

You will then repeat this displacement method for the metal cylinder: spring scale readings before and after submersion, water levels before and after removing the cylinder, mass and volume in SI units, density, and percent error compared to the standard cylinder density you found from the caliper and balance.

For the ping-pong ball, you will work with a floating object. The ball sits in a cup of water, with an index card across half the top. You add water until the ball just touches the card. Using the depth rod of the caliper, you measure the “cap height” of the part of the ball sticking out of the water. From the diameter of the ball and this cap height, you calculate the total volume of the ball, the volume of the spherical cap above water, and the submerged volume. Using Archimedes’ principle, you then find the density of the ball from the ratio of submerged volume to total volume and the density of water.

In the last part of the lab, you work with the helium balloon. You begin by converting the room temperature to Kelvin. Then you use the barometer to read atmospheric pressure on three different scales and convert all three to pascals, checking that they agree. You use the U-tube manometer to find the pressure increase inside the balloon relative to atmosphere, and so obtain the absolute pressure $P_{balloon}$. You measure the volume of the balloon with the box-and-peanuts method, converting the result to cubic meters. You measure the lift of the balloon with the spring scale and hanger. Then, using PV = nRT, you calculate the number of moles of gas in the balloon, assume pure helium to find the helium mass and weight, use the volume to find the buoyant force from displaced air, and combine these to get the theoretical net lift. Finally, you compare the theoretical lift to the measured lift.