PHY 200 Buoyancy Lab Name ________________________________

Date: ________________ Lab Partner ________________________________

A fluid exerts an upward buoyant force on objects placed in the fluid. The magnitude of the buoyant force equals the weight of the fluid displaced by the object. This is called Archimedes' Principle.

We also have a formula for the weight of the displaced fluid:

Weight of the displaced fluid = fluid density x displaced volume x **g**

A helium-filled balloon is an example of an object that experiences a buoyant force, equal to the weight of the displaced air. For a balloon, the "fluid density" is the density of air and the "displaced volume" is the exterior volume of the balloon.

Balloons rise in the air if the upward buoyant force on the balloon is greater than the weight of the balloon (including the weight of the gas inside the balloon). Helium is often used inside a balloon because its weight is so much less than that of an equivalent volume of air. Other gases have different intrinsic densities under the same atmospheric conditions and may weigh less or more than that of the same volume of air. Neon, for example, is also "lighter than air" and when placed inside a balloon can also cause it to rise.

Here at the surface of the earth, we live submerged at the bottom of an ocean of fluid air. Under the influence of gravity, its weight presses against us from all directions and this force distributed over the area of our bodies is the atmospheric pressure we can read from a barometer. (The pressure we feel when under water exists for a similar reason.) Since there is less air piled up on top of us at higher altitudes, the atmosphere becomes less dense or "thinner", the pressure outside a rising balloon decreases, and thus the balloon expands as it rises (much like the rising bubbles exhaled by a scuba diver). If the rubber membrane reaches its elastic limit and does not burst, the volume and therefore the density of the internal gas stabilizes and the balloon stops rising when the density of the surrounding air has diminished to nearly as little as the gas inside the balloon.

At lesser altitudes, we can keep a helium or neon-filled balloon from rising by attaching additional weight to it (we call that extra weigh the "load"). If we attach just barely enough extra weight to the balloon to make it hover at a constant altitude, so it doesn't accelerate upward nor downward, then the net force on the balloon must be zero. Only in this case, the upward buoyant force is equal in magnitude to the total weight of the balloon, string, helium, and the load.

By combining the above facts into an equation, we get:

Total weight of balloon apparatus = density of air x volume of balloon x **g**

If the combined total weight of the balloon, string, helium, and load is known and if the volume is known from the balloon's dimensions, then this equation can be solved for the density of air. This is the objective of this experiment.

1. Your instructor will provide you with the standard textbook density of helium, which occurs at a temperature of 0 ˚C and a pressure of 101300 Pa, but obviously you will have to correct these for today's current room temperature and atmospheric pressure. (Since the room is much warmer than 0 ˚C, your corrected densities should be slightly smaller than the value you would find in the textbook, likewise if today's pressure is less than the standard.) Speculate about how a ratio called a "correction factor" relating today's conditions to standard conditions might allow this correction to be made by simple multiplication.

2. Carefully determine the combined mass of an empty balloon and a piece of string about a meter long which you can use to keep the balloon from escaping after it's inflated.

3. Inflate the balloon to party-size with helium, tie off the end and then attach your string (and be careful with the helium – it's high-purity so please don't waste it.)

4. Add just enough extra mass to the string so the balloon just barely floats (ideally it will neither rise nor fall, but air currents make it impossible to get it perfectly still). Try the smallest slotted metal disks, paper clips, and tape for tiny increments of extra mass. This is a tedious process that will take some time to achieve the less than 5% error required for this lab. NOTE: Neither the balloon nor string can touch or drag against any surface whatsoever or something other than the buoyant force will be supporting its weight. When you have the right amount, remove it from the string, and measure this load mass.

5. Measure the balloon's circumference or diameter, whichever you can do more precisely. Since it's not really spherical, measure a couple of ways and calculate the average. Record these values and then calculate the radius.

6. Using the geometry formula for the volume of a sphere, find the volume of the balloon.

7. Calculate the mass of the helium in the balloon.

8. Find the total mass of the inflated balloon apparatus, and then calculate its total weight.

9. Using data from your balloon experiment, solve the appropriate equation for the density of the air in this room today. Remember, the number of significant figures in your result should be consistent with the precision of individual data used to calculate it.

10. Obtain the standard textbook density of air, correct it for today's weather, and calculate the percent error between it and the experimental density of air found in the preceding step. If greater than about 5%, see instructor or correct your mistakes. In all cases, write more than one <u>specific</u> reason for any discrepancy, supporting your statements quantitatively.

11. What might you change in this experiment to make the result more precise? More accurate?