PHY 100's 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. The standard textbook density of helium which only occurs at a temperature of 0 ˚C and a pressure of 101300 Pa is $\rho_{He} = 0.179$ kg/m^3, but obviously you will have to correct this for today's current room temperature and pressure. (Since the room temperature 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. Use the correction formulas (on the worksheet or chalkboard) and current temp & pressure readings from the thermometer and barometer.

2. Carefully determine the combined mass of an <u>empty</u> balloon and a piece of string about a meter long which you can use to keep the balloon from escaping after it's inflated. Read the digital balance to its full precision. Record that reading in grams <u>and</u> in kilograms in the space below.

   Combined Balloon & String mass =

3. Inflate the balloon fully with helium, tie off the end first 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 floats (ideally it will neither rise nor fall, but air currents make it difficult to get it perfectly still). Try the smallest slotted metal disks, paper clips, and tape for tiny increments of extra load mass. NOTE: The balloon, string, and load cannot 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 of load, remove it from the string, and place it on the digital balance to measure all of the added mass as precisely as you can. Record in the space below, again in both grams and kilograms.

   Load mass =

5. Measure the balloon's circumference with a tape measure. Since it's not really spherical, first measure the longest circumference, then take the shortest circumference, and calculate the average of the two to get a reasonable approximation of an equivalent spherical circumference. Record both the measurements and average circumference in meters. Also calculate the radius from the average circumference and enter it in meters. Do you know how to find the radius if you know the circumference?

6. Using the geometry formula for the volume of a perfect sphere, find an approximate volume of the balloon in cubic meters.

7. Using the corrected density of helium (shown on the separate worksheet or on the chalkboard) and the volume of the helium, calculate the mass of the helium inside the balloon.

8. Add the mass of the empty balloon with its string (from step 2) plus the mass of the added load (from step 4) plus the mass of the helium in the balloon (from step 7) to get the total mass of the balloon apparatus. Also, calculate and record the total weight of the balloon apparatus.

9. Solve the equation from page 1 for density of air using total weight (or solve the equation given on the chalkboard for density of air using total mass.) Note: This equation contains results from YOUR balloon measurements, therefore it yields YOUR experimental answer for density of air, ρ_{AIR}, a density which occurred in this classroom due to today's atmospheric temperature and pressure. (Do not use the density correction equations here, because those simply correct textbook densities for what the text values would become under *today's* weather conditions. Obviously, the correction formulas do not contain any results from your balloon experiment.) Remember, the number of significant figures in your result should be consistent with the precision of individual data used to calculate it.

$\rho_{\text{AIR EXPERIMENTAL}} =$

10. Correct the standard textbook density of air, 1.29 kg/m^3, for today's weather the same way you did for Helium. This gives you an appropriate comparison for your experimental answer in the preceding step. Then calculate the percent error between the two. If greater than about 5%, see instructor or correct your mistakes. In all cases, write <u>specific</u> reasons for any discrepancy and support them with evidence you actually witnessed, not speculation. (Do not mention personal mistakes nor the fluctuations in the last digit on the pan balance.) What might you change in this experiment to make the result more precise?

$\rho_{\text{AIR TEXT CORRECTED}} =$

% ERROR =

Corrections to Textbook Densities for Weather Conditions Today:

$P_{ATM\ TODAY}$= ____________ $P_{ATM\ STANDARD}$= 101300 $^N/m^2$

$T_{ATM\ TODAY}$= ______˚C = ______K $T_{ATM\ STANDARD}$= 0^o C = 273.15K

$$\rho_{\substack{HEL\ TEXT \\ CORRECTED}} = \rho_{HEL\ TEXT} \times \left(\frac{T_{ATM\ STD}}{T_{ATM\ TODAY}}\right)\left(\frac{P_{ATM\ TODAY}}{P_{ATM\ STD}}\right) = \boxed{}$$

USE TO FIND HE MASS

ρ → Greek letter "rho" is symbol for DENSITY

$$\rho_{\substack{AIR\ TEXT \\ CORRECTED}} = \rho_{AIR\ TEXT} \times \left(\frac{T_{ATM\ STD}}{T_{ATM\ TODAY}}\right)\left(\frac{P_{ATM\ TODAY}}{P_{ATM\ STD}}\right) = \boxed{}$$

USE ONLY FOR % ERROR

$\rho_{HELIUM\ TEXT} = 0.179\ ^{kg}/m^3$

$\rho_{AIR\ TEXT} = 1.29\ ^{kg}/m^3$

} Only true at Standard T &P!!