Name______________________________ Partner__________________________

Date_______________ Course & Section____________________

PHY100's: Relationship Between Pressure and Volume of a Confined Ideal Gas at Constant Temperature – **Boyle's Law: PV=C**

Pressure is the force on a surface divided by the area over which the force is applied. In gases, the force comes from the impact of the moving gas molecules striking the surface. Suppose a sample of gas is sealed in a container that can expand or shrink. The pressure of the gas against the inner surfaces of the container will vary as the container's size is changed. This is because the enclosed gas molecules, each striking the surface with a certain average impulse, will concentrate their impacts over a smaller area if the container shrinks, and spread their impacts over a larger area if it expands. At the same time, in a smaller container, the molecules simply hit the container's surface more often. The combination of these two effects causes the pressure to increase as the volume decreases, and cause the pressure to decrease as the volume increases. The molecules are moving because of kinetic energy from thermal agitation, so a higher temperature would also increase the kinetic energy, and thus increase impact force and pressure, but for now, let's assume that temperature is held constant along with the amount of the gas.

We can construct a quantitative statement about the pressure exerted by a confined gas and the volume occupied by the gas by calculating the pressure in a sealed container of known volume. The mathematical relationship between the pressure and the volume is called Boyle's Law.

You will measure the volume of some air trapped in a capped syringe as you apply various forces to the plunger. Newton's Laws tell us that if the plunger is not accelerating (in fact, it won't be moving at all when you take your data), then the net force on it must by zero. For any particular applied force on the plunger, there will be one position of the plunger where the plunger comes to rest and remains in that position. To find this " equilibrium position", we push gently on the plunger to break static friction and let it rebound. With the piston in that position, the forces exerted downward on the piston must be equal to the upward force on the plunger.

When the syringe is stood upright on the table with the cork pointing down, the total downward force on the plunger comes from the weight of the plunger assembly (including added objects), $W_{plunger}$, along with the force of the atmosphere $F_{atmosphere}$. The only upward force is due to the trapped gas F_{gas}.

To summarize in the form of an equation, at equilibrium:

$$F_{gas} = W_{plunger} + F_{atmosphere} \qquad (1)$$

Since pressure is defined as force divided by area, the pressure of the confined gas is equal to the force it exerts divided by the surface area over which it contacts the plunger tip, so:

$$P_{gas} = F_{gas} / A_{plunger} \qquad (2)$$

With the force in Newtons and the area in square meters, the pressure is in units of Newtons per square meter, N/m^2, also called Pascals (Pa.)

The force on the exterior of the syringe due to atmospheric pressure is similarly

$$F_{atmosphere} = P_{atmosphere} \times A_{plunger} \qquad (3)$$

The atmospheric pressure varies with the weather conditions (lower pressure on rainy days, etc.) The instructor will provide the value for today from a barometer. The force due to the atmospheric pressure is about the same for every data point, so you only need to calculate it once and use the same value for all the trials. (Note that the mass of the outer cylinder of the syringe does NOT contribute to the weight acting on the plunger, so it is irrelevant. Don't try to measure or use it. Do not remove the plunger from the syringe body at any time.)

Procedure:

1. The precise total mass of the sliding plunger assembly (whose weight bears down on the trapped gas) has been measured previously and is printed on the wooden platform that is part of the plunger. Record below.

   Mass plunger assembly = __________

2. Obtain the precise diameter of the black rubber piston from your instructor. Calculate the radius, cross sectional area, and as always, maintain the proper compliment of significant figures.

   Diameter = _______________
   Radius = _______________
   Area plunger tip, $A_{plunger}$ = __________________

3. Based on your measurements of P_{atm} and $A_{plunger}$ calculate
   $F_{atmosphere}$ = ____________________

4. Remove the stopper plug or cork from the needle end of the syringe, and set the initial syringe air volume to 65 cubic centimeters. Seal the syringe by twisting-in the stopper plug very tightly. With the apparatus standing on the table with the stopper plug on the bottom, gently push down on the plunger piston just a little until you feel slight increasing resistance. Release the plunger and let it rebound to an equilibrium position. The weight of the plunger, $W_{plunger}$ and friction keeps it from returning all the way to 65 mL. Read your trial #1 Volume data point and enter in the data table. Read all volumes as precisely as possible. Gas can sometimes escape around the piston and/or cork and ruin your subsequent trials (especially if it gets dirty). If the plunger returns to this first Volume reading after you finish your trials, then you can be sure that no air escaped. Report whether it does or does not!

5. The total applied force or total $W_{plunger}$ is equal to the combined weight of the plunger PLUS any metal objects added. Carefully add to the plunger platform a precisely measured mass close to 0.5 kg, give another gentle push to the plunger and take a volume reading when it rebounds to a new equilibrium position. This is your volume data for trial# 2, where the total plunger mass, $m_{plunger}$ consists of the plunger plus the added metal. Place additional

increments of nearly 0.5 kg on the wooden platform for each of eight trials, and remember to always break static friction by giving the plunger a gentle uniform push after changing the load mass and noting a slight rebound before taking a precise volume reading. Record all measurements and calculated values in the table. As always, neatly show at least one carefully labeled sample of every type of calculation.

TABLE 1:

Trial #	Total $m_{plunger}$	Total $W_{plunger}$	F_{gas}	Volume, cm^3	Volume, SI

6. From the forces in the F_{gas} column of table 1, and the area of the piston face over which that force is applied, the pressure of the trapped gas can be calculated using the basic relationship between pressure, force, and area. Also, calculate the product of the pressure and the associated volume and enter the values in table 2.

TABLE 2:

Trial #	P_{gas}	$P_{gas} \times V_{gas}$

7. The pressures you calculated should all have been greater than atmospheric pressure. Why?

8. Is a pattern apparent in the data? Do the data suggest the presence of any systematic errors or flaws in the experimental equipment or procedure? How might the experiment be improved?

9. Suppose you put so much weight on the plunger that the volume was reduced to only 1.0 ml. What do you predict the pressure inside the syringe would be then? Show the simple calculation, and explain your reasoning. (Remember PV=C) Comment on the feasibility of performing such a trial.

   V = 1.0 ml
   P = __________________