PHYS 1401
General Physics I

EXPERIMENT 11
BOYLE's LAW

I. INTRODUCTION

The objective of this experiment is to study the relationship between the pressure and volume of an air sample at constant temperature. This will be done by measuring the pressure of a constant amount of air contained in a cylinder as the volume of the air is varied. The results will be compared with the predictions of Boyle's law and the ideal gas law.

II. THEORY

Boyle's law states that, for constant temperature, the product of the volume and the pressure of an ideal gas is a constant.

$$PV = C \tag{1}$$

The ideal gas law

$$PV = nRT \tag{2}$$

states that this constant (nRT) is proportional to the amount of ideal gas in the sample (the number of moles, n) and the absolute temperature, T. The constant R in this equation is the universal gas constant which has a value of $R = 8.31\,\mathrm{J}/(\mathrm{mole.K})$ in SI units. Note that if T is held constant throughout the experiment, then the ideal gas law reduces to Boyle's law.

III. APPARATUS

Pressure sensor, syringe and computer.

IV. EXPERIMENTAL PROCEDURE

1. Connect the open end of the syringe to the pressure sensor. Open the valve and pull the plunger back to set the initial volume of the air in the cylinder at $20.0\,\mathrm{cm}^3$. Close the valve.

2. Connect the pressure sensor to Channel (1) of the LabPro.

3. Open the following folders and programs: **Logger pro**, then **Experiments**, then **Probes and Sensors**, then **Pressure Sensors** and **Boyle's Law**. Click ok on sensor confirmation.

4. Before you start taking data, make sure that the volume of the air is still $20.0\,\mathrm{cm}^3$. If not make the necessary adjustments to restore the volume to $20.0\,\mathrm{cm}^3$.

5. With the volume at $20.0\,\text{cm}^3$ click on **collect**, then click **keep**. The computer will record the pressure (in kPa) and will ask you to enter the volume in ml ($1\,\text{ml} = 1\,\text{cm}^3$). Note that this initial pressure is the atmospheric pressure.

6. Move the plunger to the next volume in the data table, click **keep** and enter the volume when prompted by the computer. Be very careful with the volume measurement. It is crucial to the success of this experiment.

7. Repeat the above process for all the given volumes. You will have eleven data points. Click **stop** to end the data-taking session.

8. As the data are recorded, the computer will plot the pressure (in kPa) vs. volume (in cm^3).

V. ANALYSIS

1. The following is a series of computer calculations which will allow you to calculate the constant on the right hand side of Boyle's law, C.

2. You would like to get the computer to multiply the pressure and volume data. Go to **data** on the main menu and scroll down to **new calculated column**. In the dialogue box, call this column PV. You will calculate this product in units of Joules.

3. To enter the equation for the new column, go to "variables (columns)" and choose "pressure". Then multiply by "volume" chosen the same way. Multiply this product by (0.001) to change the units to Joules. Click **done**

4. Are the numbers in this column very close to each other? If they are, then PV is a constant. To calculate the value of this constant, find the average of all the numbers in this column. Call this average C as was done in equation (1).

5. Using the thermometer hanging on the wall of the lab, read the temperature in Celsius and convert to Kelvin.

6. Calculate the number of moles of air in the air sample using the equation:

$$n = \frac{C}{RT} \tag{3}$$

   where $R = 8.31\,\text{J}/(\text{mole.K})$ and T is the absolute temperature.

7. To check the validity of the data, you will calculate the number of moles of air from the theory. It is known that one mole of an ideal gas at STP ($T = 273\,\text{K}$ and $P = 1\,\text{atm} = 1.01 \times 10^5\,\text{Pa}$) occupies a volume of $22.4 \times 10^3\,\text{cm}^3$. Using your knowledge of the initial volume, temperature and pressure of the air, you can calculate the number of moles. First use the equation

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \tag{4}$$

to calculate the volume at STP. Note that in the above equation $P_1 = P_2 = 1.0\,\text{atm}$ and variables which have subscript 1 refer to room conditions and subscript 2 refer to STP.

8. Find the number of moles of air by dividing by the volume of one mole.

9. Calculate the percent difference between the number of moles calculated from the data and from the theory.

$$\%\,\text{diff.} = \frac{|n_{\text{exp}} - n_{\text{th}}|}{\left(\dfrac{n_{\text{exp}} + n_{\text{th}}}{2}\right)} \times 100. \tag{5}$$

10. Calculate the percent difference between the largest and the smallest values of the product PV.

11. Write a conclusion summarizing your results. Comment on the success of this experiment. Explain any percent differences which are larger than 10%. Is your result in agreement with Boyle's law? What do you think are the two most important sources of error in this experiment?

Experiment (11) Data Table		
Volume of Air Sample V (cm^3)	Pressure P (kPa)	PV (J)
20.0		
19.0		
18.0		
17.0		
16.0		
15.0		
14.0		
13.0		
12.0		
11.0		
10.0		
Average value of PV in Joules, $C =$		
Number of moles in the air sample, $n = \frac{C}{RT} =$		

$V_1 = 20.0\,\text{cm}^3$	$V_2 =$
Room Pressure, $P_1 = 1.0\,\text{atm}$	$P_2 = 1.0\,\text{atm}$
Room Temperature, $T_1 =$	$T_2 = 273\,\text{K}$
Number of Moles, $n = \frac{V_2}{22,400\,\text{cm}^3} =$	