

BOYLE'S LAW

Saddleback College Physics Department

Purpose

To compress a gas at a constant temperature, noting how the gas pressure and the gas volume are related, then use a P vs. V graph of this information to verify Boyle's Law.

Theory

The cross sectional area, A , of the syringe will be calculated using $A = \pi r^2$, where r = the radius of the syringe.

The gauge pressure, P_{gauge} , is the pressure in excess (or deficiency) of atmospheric pressure, P_{Atm} . The absolute pressure is the sum of the gauge pressure and atmospheric pressure.

$$P_{absolute} = P_{Atm} + P_{gauge}$$

The gauge pressure will be calculated using $P_{gauge} = \frac{Force}{Area}$.

The following values and conversions may be helpful:

$$P_{Atm} = 1 \text{ atmosphere} = 14.7 \text{ psi} = 1.013 \times 10^6 \text{ dynes/cm}^2 = 1.01 \times 10^5 \text{ Pascal}$$
$$1 \text{ Pascal} = 1 \text{ N/m}^2 \quad 1 \text{ cc} = 1 \text{ cm}^3 = 1 \text{ ml} = \underline{\quad} \text{ m}^3 \text{ (you fill in the blank)}$$

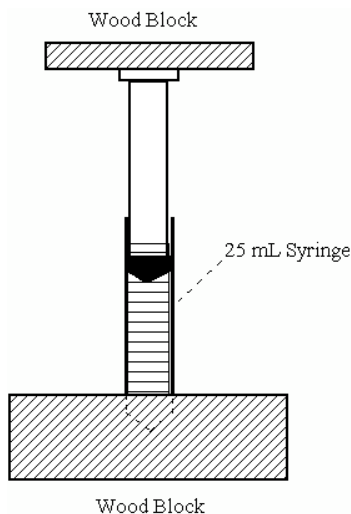
Historically, Boyle's Law was a stepping stone to the Ideal Gas Law.

$$\text{BOYLE'S LAW} \left\{ \begin{array}{l} P_i V_i = P_f V_f \\ \text{or} \\ PV = \text{constant} \\ (\Rightarrow P = \text{constant} \cdot V^{-1}) \end{array} \right.$$

- P = pressure and V = Volume
- where temperature, T , is constant and the number of moles of gas, n , is constant.

Equipment

Plastic Syringe with Wooden Base and Wooden Platform on top, masses and rod that passes through center of all masses (one 5 kg mass, two 2 kg masses, $\frac{1}{2}$ kg mass, $\frac{1}{2}$ kg weight hanger (i.e. a total mass of 10 kg), water, calipers, balance



Procedure

- 1) Obtain a Boyle's Law apparatus and the weights described above.
- 2) Determine the mass of the rod that passes through the center of all of the masses and the mass of the wooden platform that goes on top of the syringe.
- 3) Remove the plastic cap on the small end of the syringe and pull the piston out of the syringe cylinder. Using calipers, measure the inner diameter of the syringe cylinder and record this in your lab notebook.
- 4) Insert the piston back into the cylinder, adjusting the syringe volume to $V_i = 30$ ml (without the wooden platform placed on top), then cap the syringe with the plastic cap. When the air contained in the syringe is at room temperature, its pressure will be one atmosphere. This is your first data point, record these values in a table like that shown below.
- 5) Place the wooden platform on the syringe and record the volume of the gas and the mass of the platform. Place the rod (that goes through the center of all the weights) on the platform and record the volume of the gas and the mass of the rod.
- 6) From this point forward, add mass (placing each mass on the center rod) in increments of ~ 1 kg, so the air sample is gradually compressed (therefore a constant temperature is maintained). Record the values of mass, M , placed on the platform and the volume of the gas, V , in the table as you proceed. Continue until 10 kg has been added to the platform. Take care to keep the platform level, and the piston vertical, as the system gets top-heavy and unstable. Be careful, the weights are heavy.
- 7) Now repeat the volume measurements, as the masses are removed one at a time. Record these results in your table.
- 8) Once all the masses have been removed, remove the platform and extract the syringe from the wooden base. Remove the plastic cap and purge the cylinder of air. Place the tip of the syringe in

a small beaker of water and fill the syringe with water above the starting volume of 30 ml. Hold the tip of the syringe upward over the sink and force any air bubbles out. **Cap the syringe tightly** when the 30 ml volume has been attained.

- 9) **WORK OVER/IN THE SINK FOR THIS STEP.** Return the filled syringe to the wooden base in the vertical position, add the wooden platform and carefully add a 5 kg mass. Record the water volume and the mass on the syringe. Try ~10 kg on the platform...carefully! Record the water volume and mass on the syringe.

Analysis

- 1) Sample Data Table and spreadsheet layout: (One person in each lab group must record the data directly into a lab notebook, to prevent loss of data if computer fails. Notice that raw data is in column 1 and column 5, all other columns contain calculated values.)

Column #	1	2	3	4	5
Trial #	Mass added (kg)	Force (N)	Gauge Pressure (Pa)	Absolute Pressure (Pa)	Volume (m ³)
1					
2					
3					
Etc....					

- 2) An Excel spreadsheet will be used in the analysis of this lab. Your instructor will show you how to construct and use a spreadsheet to compute the gauge pressure for each mass in the table.
- 3) Compute the absolute pressure for each trial in your table, using the corresponding gauge pressures.
- 4) Use Excel to make a P-V diagram. Plot a graph of absolute pressure (vertical axis) verses air volume (horizontal axis). Draw the “Best Fit Curve” which will be the “Power fit” and choose “Display Equation on Chart”. Be sure to title your graph and label your axes with the appropriate physical quantity and units.
- 5) Compare the equation on your graph to Boyle’s Law in the form below:

$$P = \text{constant} \cdot V^{-1}$$

by calculating a **percent difference between their respective exponents** (i.e. - 1 = theoretical value).

Questions

- 1) Compare the behavior of the water with that of the air. Is water compressible? Explain the difference, if any, between the water and air by looking at the molecular level.
- 2) If we did not account for the mass of the wooden platform or the mass of the center rod, would our results be any different? Why or why not?

In your conclusion, be sure to summarize all of your results, showing all of the experimental (calculated) values and all of the theoretical values as well as their respective % differences.