Lab 31: Under Pressure – Gases and Pressure[1]

Goals: Improve ability to record observations; see how pressure differences manifest macroscopically.

Equipment: We begin with a series of demonstrations. Include descriptions/sketches of the various demos in your lab notebook.

Groups & Lab Notebook: Observe as a class. Update Table of Contents. General Lab Notes guidelines.

Part 0: The Heat is On, The Pressure's High, Tell Me Can You Feel It?

Demo-Station A: HullaBalloon. Pour a small amount of boiling water into a flask; make sure it is nice and steamy in the flask. Quickly stretch a balloon over the mouth of flask. Observe what happens to the balloon as soon as you put it on and for about 2 minutes. Check in on the flask approximately every 5 minutes.

Demo-Station B: Weight It. Determine the mass of a vessel with air and with air removed.

Demo-Station C: See It. Place an inflated balloon into the pressure chamber. Use the vacuum port to pump air out the chamber. Observe the balloon. Push the release valve to allow air into the chamber. Observe the balloon.

Demo-Station D: Feel it. Compare the difficulty of pulling apart the Magderburg sphere halves with air between them and with air removed. Play around with some suction cups. If you have time at the end, try it for yourself.

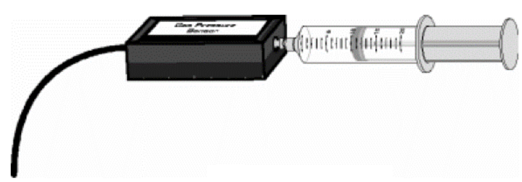
Demo-Station E: I Can Crush You. Heat a small amount of water in a soda can until steam emerges from the can. Quickly invert the can into a container of ice water such the water creates a seal around the can opening.

Goals: Improve communication and teamwork capacities**;** Improve confidence in hands-on work with equipment; Improve ability to make, describe, and record observations; use a pressure sensor attached to a syringe or a syringe-flask combination to investigate the relationship between pressure and volume at constant temperature for a fixed amount of gas; use linearization of data to determine an unknown volume.

Groups & Lab Notebook: Groups of 2. Update Table of Contents. General Lab Notes guidelines.

Equipment: You will be oriented to the equipment for today's investigations; data will be collected as a class. Make sure you include sketches of the various experimental set-ups in your lab notebook.

Part 1: Pressure Sensor and Syringe (we'll gather data as a class)



1. The pressure sensor is attached to the LabQuest and connected to the computer, with LoggerPro launched.
2. Set the syringe to an indicated volume; record this volume. Then, attach the syringe to the pressure sensor as in the figure; record the pressure at this volume.
3. Slowly decrease the **volume** to ½ of its original value; record the corresponding pressure.
4. Slowly adjust the plunger so that the **pressure** is ½ of its original value; record the corresponding volume.
5. (discuss with partner and then with class) Slow processes like this where no care was taken to insulate the gas from its surrounding can be treated as constant T processes. Additionally, this was a fixed N process. Use this information and the ideal gas law to make sense of the measurements you made – are your results consistent with the predictions of the ideal gas law?
6. Next, a series of careful measurements will be taken. Rather than Time-based mode, data will be collected in Events with Entry mode. Change the data-collection mode and enter **volume** as the Column Name and **mL** as the Units.
7. Disconnect the syringe from the pressure sensor. Set the syringe to the volume indicated. Connect the syringe to the pressure sensor.
8. Begin data collection. Click or tap Keep and enter the appropriate reading in the volume field. Slowly pull on the piston until the volume has increased by 2 mL from its previous position. When the pressure reading stabilizes, click or tap Keep and enter the volume. Repeat this step, each time increasing the volume by 2 mL until at least 6 data points have been collected (more is better if possible). The file will be saved to the Handouts folder.

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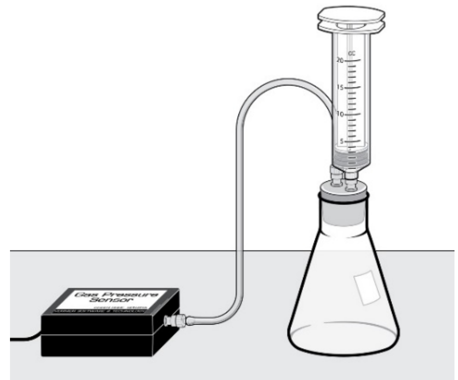
[1] All images from Vernier. Parts 1 - 4 based on experiments in Advanced Physics – Beyond Mechanics, by Vernier

Part 2: Pressure Sensor and Syringe+Flask (we'll gather data as a class)



1. Disconnect the syringe from the pressure sensor and set it to 0 mL by pushing the plunger all the way forward. Set up the system as in the figure with the 0 mL syringe.
2. Re-launch LoggerPro. Use Events with Entry mode, with **syringe volume** as the Column Name and **mL** as the Units.
3. Start data collection. Click or tap Keep and enter 0 (the reading for the syringe) in the volume field. You might wonder about this choice - note what you are wondering about if this the case in order to address it later.
4. As before, collect at least 6 data points. File saved as above.

Part 3: Analysis of Part 1 Data

1. Open up the data file, saved in Handouts folder in the program file share.
2. Produce a graph of pressure vs. volume (careful: what goes on what axis?). Make sure to plot individual data points not connected by line segments.
3. Show that the ideal gas law *PV* = *NkT* can be solved for pressure to obtain *P* = *NkT/V*. We assumed that this slow process was a constant temperature ("isothermal") process. We also assumed the amount of gas was fixed. This means that *NkT* is a constant, so call it *NkT* = *A* so that *P* = *A/V*. This is an inverse relationship.
4. Determine how well your data follows this inverse relationship by doing a Curve Fit of your data to an Inverse function. You may have to Try Fit several times, and may have to put in a seed value for *A*.
5. Consult with your instructor. After consultation and on obtaining a good fit, record the best-fit value for *A* along with its uncertainty. Save your graph for later inclusion in your lab notebook. Save your LoggerPro file to the appropriate folder in the Workspace with a useful name including your group member names.

Part 4: Analysis of Part 2 Data

1. Open up the data file, saved in Handouts folder in the program file share. Produce a graph of pressure vs. volume. Make sure to plot individual data points not connected by line segments.
2. What strikes you about this graph, especially as compared to the nominally similar graph from Part 1? Discuss with your partner why you think this has occurred.
3. Your discussion should have led you to realize that in this scenario, the volume reading on the syringe is not the volume of the system – the system volume is comprised of the volume of the flask + tubing (which is fixed) + the volume of the syringe (which is varied). Then, $V = V_0 + V_{syringe}$ where V_0 = volume of flask + tubing is a constant. How can we account for V_0? An inefficient and inelegant method is to make a new calculated column for system volume where you keep guessing a value for V_0 and keep fitting until you think you have a good fit. Instead, we will use a method known as linearizing, discussed next.
4. Show that for this case, the ideal gas law can be re-written as $V_{syringe} = A\left(\frac{1}{P}\right) - V_0$ (where $A = NkT$ is a constant).
5. This is a linear equation of the form $y = mx + b$, where $x = \frac{1}{P}$ and $y = V_{syringe}$. What do m and b correspond to, both in terms of symbols and physical quantities, and in terms of the linear graph?
6. So, if we plot $V_{syringe}$ vs. $\frac{1}{P}$ and obtain a straight line (hence the term linearization), we can show that the ideal gas law applies to this situation and obtain $A = NkT$ and V_0 at the same time.
7. Create a new calculated column for $\frac{1}{P}$ called reciprocal pressure. Figure out the appropriate units.
8. Plot $V_{syringe}$ vs. $\frac{1}{P}$ (careful: what goes on what axis?), show individual data points, and obtain a best-fit straight line (use Curve Fit instead of Linear fit so you can also get the uncertainties in A and V_0.) Record the best-fit values for A and V_0 along with their uncertainties.
9. Save your graph for later inclusion in your lab notebook. Save your LoggerPro file to the appropriate folder in the Workspace with a useful name including your group member names.

Part 5: Extensions

1. From your results in Parts 1 – 4, how would you determine the amount of gas (*N*) in the two cases?
2. The pressure sensor actually has a little chamber incorporated in it. Therefore, the assumption in Part 1 and 3 that the syringe volume was the system volume is not quite accurate. The effect is not as pronounced as in Part 2 and 4 because the pressure sensor chamber volume is relatively small. Reproduce your analysis as in Part 4 to determine the pressure chamber volume.
3. Try the Demo-Station D activities with your partner.
4. Discuss the physics involved with your Part 0 observations with your partner and your instructor.