# Boyle's Law

## Theory

Consider a fixed amount of a gas bottled up in a closed container. In order to describe the state of this system, we need to know three important quantities – the pressure the gas exerts on the walls of the container, the volume the gas takes up, and the temperature of the gas. All of these variables depend on the others; but if we hold a certain variable constant we can get information about the relationship between the other two. In this manner, we will study three different gas laws.

This experiment examines Boyle's law. This law assumes a constant temperature, and examines the relationship between pressure and volume of a gas. Boyle's law states that the pressure of a gas is inversely proportional to the volume in which the gas is contained. Thus, $P = \frac{k}{V}$ where k is a constant that depends upon the particular system.

## Experiment

Investigate the relationship between gas pressure and volume using a Saltire Scientific pressure sensor.

## Materials

Casio Data Analyzer (EA-100 or EA-200)
Casio SB-62 link cable
Suitable Casio Calculator
Saltire Scientific Gas Pressure Sensor
20 mL Syringe

## Setup

This lab requires very little setup. First, make sure that your calculator is connected to the data analyzer with the link cable. Second, plug the pressure sensor into the CH-1 (channel 1) port on your EA-100 or EA-200. Switch both your calculator, and the data analyzer on. Begin with your syringe disconnected from the sensor.

## Step by Step

1. On your calculator, run the program called BOYLE. It will guide you through the experiment

2. Your calculator will instruct you to take a measurement of atmospheric pressure. Be sure that the sensor is not connected to anything for this measurement – it should be open to the air.

3. The program will now ask you to position the syringe at 20mL, and then connect it to the sensor. Be sure you position the syringe at 20mL first, so that 20mL corresponds to atmospheric pressure when you connect it to the sensor.

4. You will now be asked to move the syringe to a new position. Enter the new volume when prompted, and press EXE to take a measurement of the pressure

5. You can repeat step 4 a number of times. Try to get a wide range of pressure measurements. **Important:** *Do not compress the syringe past 5mL. Doing so could damage the sensor.*

6. When you are finished taking measurements, disconnect the syringe from the sensor. The calculator will then sort and graph your data.

## Data Table

| Volume (mL) | Pressure (atmospheres) |
|---|---|
| | |
| | |
| | |
| | |
| | |

## Sample Data

| Volume (mL) | Pressure (atmospheres) |
|---|---|
| 10 | 2.02 |
| 12 | 1.68 |
| 14 | 1.44 |
| 16 | 1.26 |
| 18 | 1.12 |
| 20 | 1.00 |

## Discussion

1. **Use Boyle's law to explain what happens to a helium balloon that is released from the ground. What happens to the volume of the balloon as it rises? Why does the balloon eventually burst?**

2. **Use one of your data points to calculate the constant *k* for your system.**

3. **On your calculator, plot the Boyle's law curve (using the *k* you found in the previous question) on the same graph as your data. How well does your data fit the model?**

4. **If your data does not lie exactly on the theoretical line, can you think of any reason why this might be so? (Hint: think about how accurate your volume measurements were. Is there any other volume that you need to take into account besides the volume of the syringe?) How might you modify your data to correct for this?**

# *Boyle's Law*

## GENERAL COMMENTS

This is a very simple experiment that takes minimal setup time, and can produce very accurate results. As stated in the experiment description, the connection between the sensor and the syringe is critical. If there are any leaks, you will not get good data. The only other caution is to be careful not to damage the sensor. As stated in the experiment, these sensors are designed to withstand up to 4 atmospheres. Thus, if you connect the syringe with the plunger at 20mL, one should not try to push the plunger past 5mL when the syringe is connected. The sensors function all the way down to 0 atm, so there is no danger in pulling the plunger out very far.

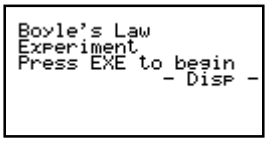
## DISCUSSION POINTS

This experiment provides an excellent opportunity for the students to compare their data with a theoretical model. As the discussion questions suggest, their data will probably not fit the model exactly. They should eventually realize that the 20mL on the syringe really only accounts for the volume in the syringe, and not the extra volume in the tube connecting the syringe to the sensor. To correct for this, the volume in the tube should be added on to each of the data points, and a new comparison with the model should be made. (Remember that the theoretical curve will also have to be modified: $k$ will have to be recalculated based on the new data.)

There are many examples of Boyle's law in the world. One of the most significant is in a heat engine – where a gas is heated up to increase its pressure. This increased pressure causes the gas to expand, usually pushing up a piston (increasing the volume.) Thus, the expansion of the gas does *work*, and the thermal energy from the heat source is converted to mechanical energy.

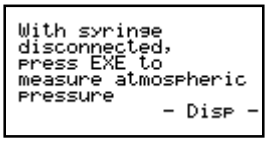
# *Boyle's Law - Calculator Program Explanation*

When you begin execution of the program, a screen appears and informs you that you have begun the Boyle's law experiment.

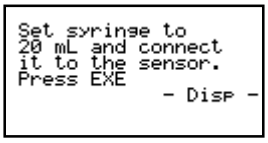



To begin, the program reminds you to plug the pressure sensor into the CH-1 port of the data analyzer. You should also make sure that the calculator is properly linked to the data analyzer.

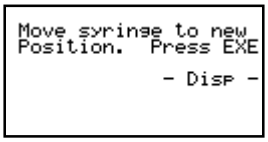

The program then asks you to measure atmospheric pressure. Press EXE to do so. Make sure that you do not have the syringe connected to the sensor at this time.



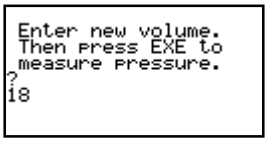

When prompted by the program, place the syringe plunger at exactly 20 mL, and *then* connect it to the sensor. This way, you have set a volume of 20 mL to correspond to atmospheric pressure.



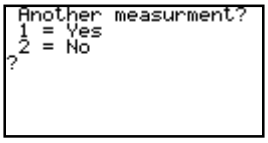

The program will then prompt you to move the syringe to a new position. You may move the syringe to any position you like, but make sure to hold its position steady.




Next, you must enter the volume at this new position. (In the screen at the right, we have moved the syringe to a new volume of 18 mL)




After this, a screen will come up asking you if you would like to take more measurements. Enter the number of your choice, and press EXE. If you select "yes", you will be asked to move the syringe again. If you select "no," the experiment will end, and a graph will be drawn. Take as many measurements as you like.




A sample graph is shown at the right. The squares represent your data points, and the line is the theoretical curve y = 20/x. Press EXE to finish execution of the program.