Boyle's Law

Name _____

Class _____

In this activity, you will explore the following:

- *the relationship between the volume of a gas and the pressure it exerts*

The primary objective of this experiment is to determine the relationship between the pressure and volume of a confined gas. The gas you use will be air, and it will be confined to a syringe that is connected to a pressure sensor. When the plunger of the syringe is compressed, the volume of air in the syringe changes. This causes a change in the pressure exerted by the confined gas. This pressure change will be monitored using a pressure sensor. It is assumed that the temperature and number of moles of the gas will remain constant throughout the experiment. Pressure and volume data pairs will be collected during this experiment and then analyzed. Using the data and graph, the mathematical relationship between pressure and volume of the confined gas can be determined. Historically, this relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's law.

Problem 1 – Preliminary Questions

Step 1: Open the file **06_Boyles_Law.tns**. Answer questions 1–3 to review your existing knowledge.

Q1. Which variable is held constant during a Boyle's law experiment?

- o pressure
- o volume
- o temperature
- o all of the above

Q2. When a quantity of gas is compressed, the pressure of the gas will

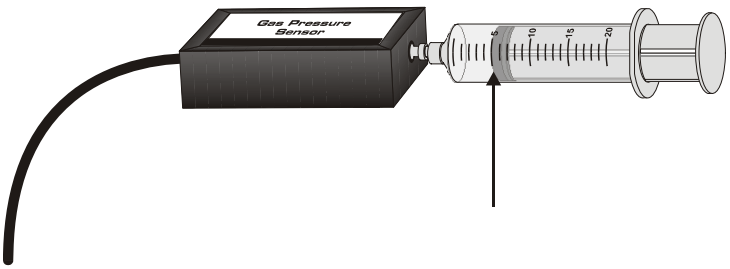
- o increase
- o decrease
- o not change
- o increase, then decrease

Q3. The mathematical relationship between pressure and volume is

- o direct
- o inverse
- o indirect
- o impossible to predict

Problem 2 – Data Collection and Analysis

Step 1: With the 20-mL syringe disconnected from the pressure sensor, move the piston of the syringe until the front edge of the inside black ring (indicated by the arrow in the figure below) is positioned at the 10.0 mL mark.



Step 2: Attach the syringe to the probe. (Do not twist too tightly; tighten it only until the syringe is firmly attached to the probe.)

Step 3: Plug the pressure probe into the EasyLink or Go!Link interface. Connect the interface to your computer or handheld.

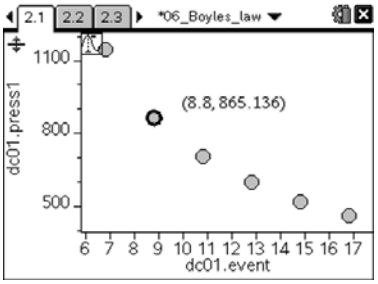
Step 4: Move to page 2.1. A data collection console should appear on the screen. Set the data collection to **Events with Entry** mode (**Menu > Experiment > Set Up Collection > Events with Entry**).

Step 5: Start the data collection. Wait for the reading to stabilize, and then press enter to record a data point. Enter the volume as the data value. **NOTE:** When you enter the volume, you need to add 0.8 mL to the reading on the syringe to account for the volume of the air in the neck of the syringe. For example, if the syringe reads 10 mL, you should enter 10.8 mL.

Step 6: Push the plunger on the cylinder in until the volume on the syringe reads approximately 8 mL. Record another data point, making sure to add the 0.8 mL correction to the exact volume reading on the syringe.

Step 7: Repeat the data collection for syringe volumes of 6 mL, 12 mL, 14 mL, and 16 mL. After you have collected all of the data points, stop the data collection and disconnect the sensor.

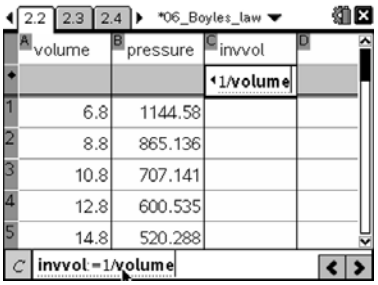
Step 8: A graph of the data should be displayed on page 2.1. To examine the data pairs on the displayed graph, use the **Graph Trace** tool (**Menu > Analyze > Graph Trace**). Use the right arrow key to move between the data pairs. Record the pressure and volume data values in the data table on page 2.2 (round the pressure to the nearest 0.1 kPa).



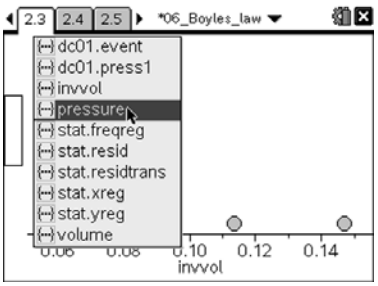
Step 9: Move back to page 2.1. Use the **Regression** tool (**Menu > Analyze > Regression**) to determine the mathematical relationship between pressure and volume. The graph of the correct relationship will fit the data very well.

Q4. What is best-fit mathematical equation relating pressure and volume?

Step 10: To confirm that an inverse relationship exists between pressure and volume, a graph of pressure vs. reciprocal of volume (1/volume) may also be plotted. First, you need to calculate the inverse of the volume. Move to page 2.2. Label column C **invvol**. In the second row (marked with the diamond symbol), enter **=1/volume** and press enter. The column should populate with the inverses of the volume measurements.



Step 11: If the relationship between pressure and volume is an inverse relationship, then a graph of pressure vs. inverse of volume should be a straight line. To test this prediction, move to page 2.3 and make a graph of **pressure** vs. **invvol**. Use the **Linear Regression** tool (**Menu > Analyze > Regression > Show Linear (mx + b)**) to plot the best-fit line through the data. The linear-regression statistics for the data will be displayed in the form $y = mx + b$, where x is 1/volume, y is pressure, m is a proportionality constant, and b is the y-intercept. When you have graphed the data and the best-fit line, answer questions 5–12.



Q5. If volume doubles, pressure will
- o be halved
- o double
- o be quartered
- o be quadrupled

Q6. If volume is halved, pressure will
- o be halved
- o double
- o be quadrupled
- o be quartered

Q7. If volume is tripled, pressure will
- o be tripled
- o be reduced to one-third
- o increase by six times
- o be reduced to one-sixth

Q8. Based on your data, is the relationship between the pressure and volume of a confined gas direct or inverse? Explain your answer.

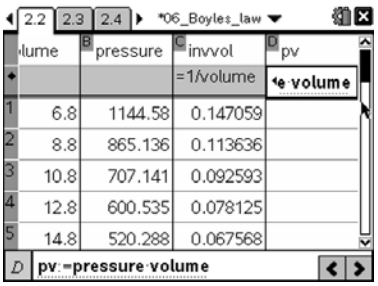
Q9. What will happen to pressure if volume increases from 10.0 mL to 40.0 mL?
- o It will increase by 300%.
- o It will double.
- o It will increase to four times its original value.
- o It will increase by 40%.

Q10. What will happen to pressure if volume decreases from 10.0 mL to 2.5 mL?
- o It will decrease by 75%.
- o It will be cut in half.
- o It will decrease to one-fourth its original value.
- o It will decrease by one-third.

Q11. What two factors are assumed to be constant in this experiment?
- o pressure and volume
- o temperature and number of moles
- o temperature and pressure
- o number of moles and volume

Q12. Write an equation describing the relationship between pressure (P) and volume (V). Use k to represent the proportionality constant.

Step 12: One way to determine if a relationship is inverse or direct is to find a proportionality constant, *k*, from the data. If this relationship is direct, $k = P/V$. If it is inverse, $k = PV$. To test your data, move back to the *Lists & Spreadsheet* application on page 2.2. Name column D **PV** and column E **poverv**. In the second row, enter **=(pressure)·(volume)** in column D and **=(pressure)/(volume)** in column E. Examine the resulting values, and then answer questions 13–15.



Q13. Which calculation, *PV* or *P/V*, produced the most constant value?

Q14. How constant were the constant values? How could you increase the accuracy of the values?

Q15. Summarize what you have learned about the relationship between pressure and volume.