Science Objectives

- Use a Gas Pressure Sensor and a gas syringe to measure the pressure of an air sample at several different volumes.
- Determine the relationship between gas pressure and volume.
- Use the results to predict the pressure at other volumes.

Math Objectives

- Mathematically describe the relationship between gas pressure and volume.
- Evaluate an inverse mathematical relationship.
- Generate and analyze a power regression model.
- Linearize an inverse relation.

Materials Needed

- Vernier® EasyLink™
- Vernier Gas Pressure Sensor
- 20 ml syringe

Vocabulary

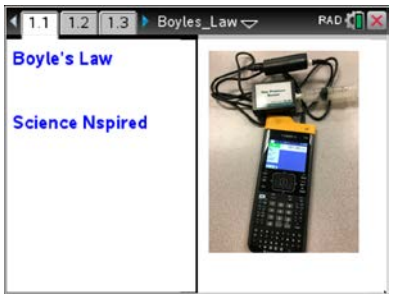
- pressure
- volume
- inverse

About the Lesson

- This activity makes use of the Gas Pressure Sensor in an inquiry activity that enables the student to understand Boyle's Law through experimentation and data collection.
- As a result, students will:
  - Built a mathematical model to show the inverse relationship between gas pressure and gas volume.
  - Analyze that mathematical model, and make predictions from the model through interpolation and extrapolation.

TI-Nspire™ Navigator™ System

- Class Capture to monitor student progress.
- Live Presenter allows students to show their graphs to the class.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Entering and graphing data
- Tracing and interpolating

Tech Tip:

Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:

Student Activity

- Boyles_Law_Student.pdf
- Boyles_Law_Student.doc

TI-Nspire document

- Boyles_Law.tns

Activity Overview

- Please print the student worksheet and make available to students before beginning the lab. Lab background information as well as lab procedures are included only in the student worksheet. Always remember to review any safety precautions thoroughly with your students prior to starting the lab.
- Students may answer the questions posed in the .tns file and submit for grading with TI-Nspire Navigator (optional) or students may answer directly on the student worksheet. Note that some questions require written responses. These can be recorded on the lab handout or in a lab notebook.

Discussion Points and Possible Answers

TI-Nspire Navigator Opportunity

Use the TI-Nspire Navigator System to monitor student progress using Class Capture.

Pre-lab Information and Questions

Have students read the background information on pages 1.2 – 1.3.

They should then read the directions on page 1.4 for the simulation on page 1.5. Based upon the simulation of the molecules moving in the closed box, students are asked to predict what a graph of pressure as a function of volume would look like.

Then, students should answer the pre-lab question on page 1.6, and predict the basic shape of the graph for pressure as a function of volume.

Q1. As volume increases, the pressure _____.

Answer: decreases

Move to page 2.1.

TI-Nspire Navigator Opportunity: *Class Capture*
See Note 1 at the end of this lesson.

Lab Procedure

The lab procedure is in the Student Worksheet and is not duplicated here. Please refer to the student handout.

The following questions appear in the Student Worksheet after the data are collected.

10. How does the graph of the data compare to your prediction?

    Answer: Answers will vary.

11. Discuss the possible mathematical models for this data set.

    Answer: Most students will suggest exponential or inverse (rational) functions. Answers may vary.

12. Based on the graph of pressure versus volume, decide what kind of relationship exists between these two variables—direct or inverse. Explain your reasoning.

    Answer: Students should suggest an inverse relationship since the pressure increases as the volume decreases.

    Teacher Tip: Students determine the equation using a Power Regression. Since the relationship is P = k/V, the equation $y = a \cdot x^b$ should fit with the value of b approximately equal to -1.

13. Examine the sign of the exponent. What does the sign indicate about the relationship?

    Answer: The value of the exponent should be close to -1. Since $1/x = x^{-1}$, the regression equation supports the idea that the relationship is reciprocal or a rational function.

14. Write the equation that models the data in two different ways.

    Answer: Answers will vary. They include P = k/V, $P = k\,V^{-1}$, and PV = k.

Have students move to pages 2.3 – 2.5, and answer the questions in the .tns file or on the worksheet.

Q2. Which variable is considered to remain constant during a Boyle's Law experiment?

Answer: temperature

Q3. When a quantity of gas is compressed, the pressure of the gas is expected to _____.

Answer: increase

Q4. The expected mathematical relationship between pressure and volume is _____.

Answer: inverse

Move to Page 3.1, and then return to page 2.2.

Students will follow the directions in the student worksheet to linearize the data.

Tech Tip: When entering the expression for the New Calculated Column, the names of variables must be entered exactly as they are in the current columns. These names are case-sensitive.

Teacher Tip: Transforming the data so that the graph produces a straight line confirms the model. If the students believe that the relationship may be P = k/V, they can take the reciprocal of the volume values and plot the reciprocal as the independent variable. If the graph of P vs 1/V is linear, the model is confirmed. The value of the slope for the linear graph should be close to the value of a, the constant in the power regression. Encourage a discussion of these relationships.

16. Calculate the regression line y = mx + b where x is 1/volume, y is pressure, m is a proportionality constant, and *b* is the *y*-intercept. Select **MENU > Analyze > Curve Fit > Linear**.

    a. Write the equation for the linear regression of Pressure as a function of 1/V.

       Answer: Answers will vary.

    b. How is the linear regression equation related to the equation that you determined for Pressure as a function of Volume?

       Answer: The slope of the linear regression equation should be close to the *a* value in the power regression. These will not match exactly due to experimental error.

Move to pages 3.2 – 3.9.

Q5. If the volume is doubled from 5 mL to 10 mL, what happens to the pressure?

Answer: If the volume is doubled, the pressure is cut in half.

Q6. If the volume is halved from 20 mL to 10 mL, what happens to the pressure?

Answer: If the volume is cut in half, the pressure doubles.

Q7. Based on the data, what would be expected to happen to the pressure if the volume in the syringe were increased from 10 mL to 40 mL?

Answer: If the volume is 4 times greater, the pressure would be ¼ of the original value.

Q8. From the answers to the above three questions and from the shape of the curve of the plot of pressure vs. volume, what is the relationship between the pressure and volume of a confined gas?

Answer: inverse

Q9. What two experimental factors are assumed to be constant during this experiment?

Answer: moles of gas and temperature

Q10. Using P, V, and k, write an equation representing Boyle's Law.

Answer: P = k/V or PV = k

Q11. Which of the following produced a constant value?

Answer: pressure times volume

Q12. Summarize what you have learned about the relationship between pressure and volume.

Answer: Answers will vary. Students should indicate the inverse relationship between pressure and volume

Move to page 4.1.

Extension: Effect of Temperature on Boyle's Law

Students will follow the instructions on pages 4.1 - 4.3 for the simulation, and then answer the following questions from pages 4.4 - 4.6.

Q13. When the temperature is doubled, how does the pressure change?

Answer: The pressure doubles.

Q14. At a higher temperature, the relationship between pressure and volume is a(an) _____ relationship.

Answer: inverse (same as before)

Q15. Vary only one variable, temperature or volume. Write about your observations of pressure based upon these changes.

Answer: Statements will vary. Volume is inversely related to pressure and temperature is directly related to pressure.

Wrap Up

Discuss how the mathematical equations $P = k/V$, $P = kV^{-1}$ and $PV = k$ are all forms of the same relationship. Ask students to explain how the motion of the molecules changes due to changes in volume and temperature. Another line of questioning is to ask for examples of these relationships with real world examples.

Assessment

Formative assessment will consist of questions embedded in the pre-lab TI-Nspire document. Summative assessment questions are found in the lab and post-lab TI-Nspire document. The questions will be graded when the TI-Nspire documents are retrieved. The Slide Show can be utilized to give students immediate feedback on their assessment.

TI-Nspire Navigator Notes

Note 1 Class Capture

Class Capture can be used to monitor students and display their graphs.