

It's A Gas!

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Overview: What happens when the pressure increases in a container? What happens to the volume of the air inside as the pressure increases? Through the use of video and the Internet, students will find the answer to each of these questions. Students will experiment with a model of a lung and watch the results of increasing pressure and decreasing the volume of air space! Students will also collect data using the Calculator Based Laboratory, graphics calculator, and Vernier Pressure Sensor. A web site about Boyle's law will help students reinforce their understanding of the relationship between pressure and volume.

Grade Levels: 9-12

Time Allotment: 1 90-minute block

Subject Matter: Mathematics, Physics

Learning Objectives: The student will be able to

- Recognize the relationship between volume and pressure.
- Identify and solve relations that are inverse functions.

Standards

Virginia Standards of Learning

<http://www.pen.k12.va.us/VDOE/Instruction/sol.html>

Standard Number: A.19

The student will analyze a relation to determine whether a direct or inverse variation exists and represent it algebraically and graphically, if possible.

Standard Number: AII.20

The student will identify, create, and solve practical problems involving a combination of direct and inverse variations.

Standard Number: PS.1

The student will plan and conduct investigations in which * length, mass, volume, density, temperature, weight, and force are accurately measured and reported using the International System of Units (SI - metric); * triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and spring scales are used to gather data; * data from experiments are recorded and interpreted from bar, line, and circle graphs; * research skills are utilized using a variety of resources; * independent and dependent variables, constants, controls, and repeated trials are identified; * valid conclusions are made after analyzing data; * research methods are used to investigate practical problems and questions; and * experimental results are presented in appropriate written form. The student will investigate and understand that the kinetic molecular theory can be applied to solve quantitative problems involving pressure, volume, and temperature.

Standard Number: PH.1

The student will investigate and understand how to plan and conduct investigations in which * the components of a system are defined; * instruments are selected and used to extend observations and

measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge; * information is recorded and presented in an organized format; * metric units are used in all measurements and calculations; * the limitations of the experimental apparatus and design are recognized; * the limitations of measured quantities through the appropriate use of significant figures or error ranges are recognized; and * data gathered from non-SI instruments are incorporated through appropriate conversions.

Standard Number: PH.2

The student will investigate and understand how to analyze and interpret data. Key concepts include * a description of a physical problem is translated into a mathematical statement in order to find a solution; * relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data; * the slope of a linear relationship is calculated and includes appropriate units; * interpolated, extrapolated, and analyzed trends are used to make predictions; * inferential statistical tests are applied in evaluating experimental data; and * analysis of systems employs vector quantities utilizing trigonometric and graphical methods.

Standard Number: PH.7

The student will investigate and understand that the kinetic molecular theory can be applied to solve quantitative problems involving pressure, volume, and temperature.

Media Components

Video:

- *Phases of Matter: Gases*, United Learning, www.unitedstreaming.com

Internet:

- Teacher Activity Index: Boyle's Law

This site allows the viewer to visualize the changes in pressure based on increased or decreased volume and likewise visualize the changes in volume when the pressure is increased or decreased. There are also sample problems for the students to solve and an activity in which the student must identify all variables. <http://fsc.fernbank.edu/chemistry/BOYLES.htm>

To fully utilize this site, get the shockwave plug-in at:

<http://sdc.shockwave.com/shockwave/download/frameset.fhtml?>

Technology:

TI-82 or 83 graphing calculator

TI -82 or 83 overhead calculator and LCD panel

Calculator Based Laboratory

Pressure Sensor

PRESSURE* program for graphing calculator

* Can be downloaded from the disk that comes with Real World Math with the CBL System Brueningsen, Bower, Antinone, Brueningsen, Texas Instruments
<http://education.ti.com/us/product/apps/latest.html> describes the set up of the system.

Materials

- For Each Student
Access to a computer and Internet
- For the Teacher
1 one-liter clear plastic bottle
1 large balloon
1 small balloon
CBL
Vernier Pressure Sensor with the enclosed syringe
Din pin adaptor
Overhead Graphic Calculator with Pressure Program loaded (The program can be downloaded from the disk that comes with Real World Math with the CBL System Brueningsen, Bower, Antinone, Brueningsen, Texas Instruments)
Graph Link to download calculator program.

Prep for Teachers

- Cue the tape or streaming video:
Phases of Matter “Gases” (4:03)
Audio cue: “...but water also demonstrates a certain degree of elasticity; a property that implies stretchiness as is seen here”
Visual cue: Water faucet and sign saying: Elasticity: ability of a substance to stretch
- Bookmark website:
<http://fsc.fernbank.edu/chemistry/BOYLES.htm>
- During the use of media provide students with a Focus for Media Interaction, a specific task to complete and/or information to identify during or after viewing segments to focus their attention.
- Directions for making a model lung: Attach a balloon to the opening of a plastic one-liter bottle. Make sure the balloon does not have any air in it. Place the balloon inside the bottle. Make sure there are no air leaks.
Cut the bottom of the bottle off and stretch another balloon across that opening. Attach the balloon securely making sure there are no leaks. Tie a knot in this balloon so that you will be able to grab it. When the bottom balloon is pulled out the balloon at the top and inside of the bottle will fill with air. This model will show how the diaphragm (the balloon covering the bottom of the bottle), works to fill the lungs with air.
- Follow the directions for setting up the pressure sensor, CBL, and Graphics Calculator found under Learning Activities. Download the program PRESSURE into the TI-82 or 83 overhead calculator using the GraphLink computer program and the disk from Real World Math with the CBL System. Practice hooking up the CBL to the pressure sensor using the din pin adaptor. Run the PRESSURE program and familiarize yourself with the experiment.

Introductory Activity

Step 1: Tell students that all gases have both volume and pressure and they can be related mathematically. Not only can they be explained mathematically but one can understand them on an intuitive level as well. Say, "Let's look at a situation that would give students insight into the relationship between pressure and volume. Suppose you were able to put 25 students in a phone booth. Obviously they would exert a great deal of pressure on each other and on the walls of the phone booth. The pressure would be so great that not only would some of the students be crushed but the phone booth would explode! Now, if we put those 25 students into an elevator, the pressure against the walls of the elevator and against the students would certainly be less than before and the elevator would not explode. What factor allowed the pressure to decrease in the elevator as opposed to the phone booth? Obviously the elevator is larger and thus the volume has increased. As the volume increased, the pressure decreased and conversely as the volume decreased, the pressure increased. This situation is similar to gas molecules in a container that bounce off of each other and bounce off the container's walls, all along, while exerting pressure on each other and the walls. We can describe this phenomenon using Boyle's Law."

Step 2: Show the students the model of the lung. As you pull down on the knotted balloon at the bottom of the "lung" say, "What happens to the balloon inside the lung?" (it expands) "Why does it expand?" (the volume has increased therefore there is less pressure on the walls of the inside balloon thus allowing it to fill up with air)

Step 3: Fill a film canister 1/3 full of water. Ask students, "What will happen if we place an antacid tablet such as Alka-Seltzer in the canister and snap on the lid?" (the pressure will become greater and the volume of air will become smaller and smaller until eventually the lid will be forced off of the canister) Drop an antacid tablet into the canister and snap on the lid and watch as the lid blows off.

Step 4: Provide students with a **Focus for Media Interaction**. Say: "Let's now look at a video clip about gases that helps explain this phenomenon. I want you to listen carefully so you can discover several of the characteristics of gases." Start the video and Pause the video at 00:45 after you see the burner ignited and the narrator says "it can have an odor as with the case of this natural gas of this stove." Ask, "What are several characteristics of gases?" (They do not have a definite shape or a definite volume, you can't see gases, but sometimes vapors can be seen. Some gases can have an odor.)

Provide students with a **Focus for Media Interaction** by saying, "In this next video clip, I want you to find out why gases can be compressed or why they can expand?" Resume video and Pause at 1:06 after you hear the narrator say "or gas can spread out and fill a large volume like the water vapor gas filling the air." Ask, "So why can gases expand and be compressed?" (Because they do not have a definite shape or volume. They can fill either a small or large volume.)

Provide students with a **Focus for Media Interaction** by saying, "Listen carefully to the next clip to determine what causes gases to expand and what happens to the container when expansion occurs?" Resume video and Pause at 1:36 after you hear the narrator say "it can be used to hammer nails into this piece of wood with tremendous force and speed" Ask, "What causes gases

to expand?” (The fast moving gas particles are more scattered. All the particle motion causes gases to expand.) “What happens to the container when gases expand?” (The gases create an outward pressure on the container.)

Provide students with a **Focus for Media Interaction** by saying, “Now we are going to watch a clip that describes the relationship between the volume of the balloon and the pressure on its surface. I want you to be able to describe what happened. I’d also like for you to listen for the definition of Boyle’s law and write it down.” Resume video and Pause at 2:06 after you hear the narrator say “Boyle’s Law states that a volume varies inversely with pressure.) Ask, “ Can you describe the relationship between the volume of the balloon and the pressure exerted upon the walls of the balloon?” (As the volume decreases when you squeeze the balloon, the pressure on the surface of the balloon increases.) “What does Boyle’s Law state?” (Boyle’s Law: The volume varies inversely as pressure. As one increases, the other decreases.)

Provide students with a **Focus for Media Interaction** by saying, “We are going to watch one more experiment and I want you to tell me how this relates to Boyle’s Law.” Resume video and Stop at 12:30 when you hear the narrator say “The pressure built up by the gas exceeds the strength of the lid and causes it to blow off.“ Ask, “Why did the lid blow off of the canister?” (As the pressure increased and the particles moved about more and more, the available volume (available space) inside the canister decreased and there was not enough room for the expanding bubbles; therefore, the lid blew off)

Learning Activities

1. Collecting Data with the CBL, graphics calculator, and pressure sensor.

- Directions for setting up the pressure sensor, CBL, and Graphics Calculator.

(Download the program Pressure into the TI-82 or 83 overhead calculator using a GraphLink.)

- Attach the end of the hypodermic syringe to the three-way valve on the pressure sensor.
- Turn on the CBL and Graphics Calculator and run the PRESSURE program.
- With the release valve open, (this will expose the pressure sensor to the atmospheric pressure) pull the plunger all the way out to fill the syringe with the maximum amount of air. To zero the probe, make sure the release valve is still open and press [ENTER]
- Close the release valve and adjust the plunger so that the volume of air in the syringe is 20 cubic centimeters. When prompted to do so, press [ENTER] to collect the pressure reading at that volume.
- Adjust the plunger to read 18 cubic centimeters then [ENTER] and that will collect the pressure reading at that volume. Continue in this manner until a total of eight data points has been collected.
- After collecting the data, a plot of pressure (in atmospheres) versus volume (in cubic centimeters) will appear on the calculator screen.
It is a good idea to run this program several times to make sure you do not get a flat graph. If this is the case, you probably have the release valve open to the atmosphere instead of to the syringe. If the release valve is not closed to the atmosphere, you will notice right away that it does not get more difficult to push the plunger in.
- Have students verbalize their experience in working with the syringe. Make sure that the students understand that the curve that is produced is an example of an inverse variation.

2. Provide students with a **Focus for Media Interaction** by saying, “We will now visit a web site to help reinforce the concepts of inverse variations.” Go to <http://fsc.fernbank.edu/chemistry/BOYLES.htm>
 - a. Ask, “How do you think gas molecules create pressure?”(accept all answers)
 - b. Click on Explanation. Say, “Pressure is exerted when the molecule strikes a surface. What do you think will happen when the volume is decreased?”
 - c. Click Next. Say, “Notice how the distance between the surfaces decreases. What effect do you think this will have on the molecules? How will they react differently as the distance (volume) between the surfaces decreases?” (accept all answers)
 - d. Click Next. (the molecule will strike the surface more often causing the pressure to increase.)
 - e. Have student summarize the concept that as the volume decreases the molecules’ activity increases, which results in greater pressure.
 - f. Click on Return to Menu.

3. Provide students with a **Focus for Media Interaction** by saying,” We are now going to see if we can develop a formula so that when given information about a certain amount of pressure and volume we can determine the resulting volume if the pressure changes or the resulting pressure if the volume changes.”
 - a. Click on Visualization and have students record all ordered pairs, (Pressure, Volume) which occur as you change one of the variables.
 - b. Ask students to look for patterns in the data. Accept all answers.
 - c. Click on Return to Menu.
 - d. Click on The Formula. Point out that the relationship between the ordered pairs can be described as pressure multiplied by the volume equals a constant.

Culminating Activity

1. **Refocus** students by saying, “We will now find an equation for the graph of the data we collected. We will also determine if the ordered pairs reflect an inverse mathematical relationship, in other words, does pressure multiplied by volume equal a constant.”
2. Return to the graphing calculator activity.
 - a. Have students press STAT and then ENTER. This will allow students to access the lists and enter the collected data into L1 and L2 of their calculator.
 - b. On the overhead calculator, use the TRACE key and the arrow keys to trace along the path of the created graph. Have students enter the volume (in L1) and pressure (in L2).
 - c. Check to see that the formula still applies to these data by multiplying the pressure by the volume. (You can do this easily by going to the top of L3 and typing L1*L2 then ENTER. (You will find that the products do not give you an exact value for the constant of variation. Discuss ways to decide what the constant should be. These might be using the mean, median or mode to determine the constant.)
 - d. Enter into the Y= menu, the equation K/X and have students store values that they chose (mean, median or mode) for the constant (K). To do this go to the home screen of the calculator and enter a value for K. To enter a value for K you should enter your approximation of K, then press STO (\rightarrow), ALPHA, K, ENTER. Experiment by storing different values of K and find the constant of variation that will give you the line of best

- fit for your data. Have students use this value of K to write a formula for this particular problem.
- e. Let the calculator find the regression equation for these data. To do this, type STAT arrow over to CALC, PwrReg, Enter. Then paste this equation into Y2. To do that, go to Y= and press VARS, 5:Statistics, EQ, RegEQ.
 - f. Check to see how close the students' equations were to the one that the calculator created. (Whenever I have done this experiment, the calculator raises X to the negative .8 power instead of the negative 1 power.) The students can get a good approximation of the graph by using various values for K .
 - g. Discuss that in real life, data do not always fit the expected mathematical model exactly. The equation is just that, a model for the line of best fit.
3. Summarize and reinforce the concept of inverse variation that states as one variable increases, the other decreases and the product of the two variables is a constant ($X \cdot Y = K$ or $Y = K/X$).

Assessment: If time permits have students take the quiz on the aforementioned web site. This can also be used as a large group activity.

Cross-Curricular Extensions

Science: Have students discover if there is a relationship between the shape of sea creatures and the amount of pressure found at the various levels.

Agriculture: Discuss ways to use pressure to get jobs done, for example, pressure washers, air wrenches, pneumatic air hammers, etc.

Community Connections

- Have a SCUBA diver or instructor visit and show students a pressure regulator and describe the effects of water pressure as one dives deeper and deeper.
- Ask a doctor or nurse to come visit the class and describe why patients must wear elastic stockings after surgery.