Globisens
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Labdisc

Applied Sciences

Boyle´s Law

Measuring air pressure in a closed container while verifying the relations between air pressure and volume

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USA Standards Correlation

FRAMEWORK FOR K-12 SCIENCE EDUCATION © 2012

The Dimension I practices listed below are called out as **bold** words throughout the activity.

Dimension 1 Science and Engineering Practices	✓	Asking questions (for science) and defining problems (for engineering)	✓	Use mathematics and computational thinking
		Developing and using models	✓	Constructing explanations (for science) and designing solutions (for engineering)
	✓	Planning and carrying out investigations		Engaging in argument from evidence
	✓	Analyzing and interpreting data	✓	Obtaining, evaluating, and communicating information

Dimension 2 Cross Cutting Concepts		Patterns		Energy and matter: Flows, cycles, and conservation
	✓	Cause and effect: Mechanism and explanation		Structure and function
		Scale, proportion, and quantity		Stability and change
	✓	Systems and system models		

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Dimension 3 Core Concepts	Discipline	Core Idea Focus
	Engineering, Technology, and Applications of Science	ETS2: Links Among Engineering, Technology, Science, and Society
		ETS2.B: Influence of Engineering, Technology and Science on Society and the Natural World
	Physical Science	PS1: Matter and Its Interactions
		PS1.A: Structure and Properties of Matter
		PS2: Motion and Stability: Forces and Interactions
		PS2.A: Forces and Motion

NGSS Standards	Middle School Standards Covered	High School Standards Covered
	MS.PS-SPM: Structure and Properties of Matter	HS.PS-SPM: Structure and Properties of Matter
	MS.PS-FM: Forces and Motion	HS.PS-FM: Forces and Motion

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Content Standards (K-12)			
✓	Systems, order, and organization		Evolution and equilibrium
✓	Evidence, models, and explanation		Form and Function
✓	Constancy, change, and measurement		

Physical Science Standards Middle School		Physical Science Standards High School	
✓	Properties and Changes of Properties in Matter		Structure of Atoms
	Motions and Forces	✓	Structure and Properties of Matter
	Transfer of Energy		Chemical Reactions
			Motions and Forces
			Conservation of Energy and Increase in Disorder
		✓	Interactions of Energy and Matter

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LEARNING OBJECTIVES

Core Objectives (National Standards):

- Develop the ability to refine ill-defined questions and direct to phenomena that can be described, explained, or predicted through scientific means.
- Develop the ability to observe, measure accurately, identify and control variables.
- Decide what evidence can be used to support or refute a hypothesis.
- Gather, store, retrieve, and analyze data.
- Become confident at communicating methods, instructions, observations, and results with others.

Activity Objectives:

The purpose of this activity is to analyze the relationship between the pressure and volume of a confined gas at constant temperature, create a hypothesis and proceed to test it using the Globisens Labdisc air pressure sensor.

Time Requirement:

45 - 60 Minutes

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Objective

The purpose of this activity is to analyze the relationship between the pressure and volume of a confined gas at constant temperature, create a hypothesis and proceed to test it using the Labdisc air pressure sensor.

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Introduction and theory

Throughout the history of science many important scientists have devoted their work to the analysis and observation of natural phenomenon, and to its description through the development of mathematical formula. Their conclusions have gradually passed into universal knowledge. For example, Avogadro, Gay-Lussac, Charles Graham and Robert Boyle studied the behavior of ideal gases between the 17th and 19th centuries. These eminent scientists contributed to the understanding of ideal gases, and established the relationships between the variables that describe them.

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Introduction and theory

? Which variables do you think we should consider when studying the behavior of gases?

? Why do you think we talk about "ideal" gases?

Carry out the experiment activity with your class so that at the end you'll be able to answer the following question:

? What is the relationship between the pressure and volume of a confined gas?

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Introduction and theory

Theoretical

We define pressure as a force applied by a body on a unit area, i.e:

$$P = F / A$$

Where P = pressure, F = force, A = area.

Therefore, a gas confined to a small container will exert greater pressure upon the container walls, compared to a gas confined to a larger container. As the walls' surface area decreases, the relationship force/area becomes greater.

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Introduction and theory

Robert Boyle and Edme Marriot studied this concept, presenting the Boyle-Marriot Ideal Gas Law. The study of general chemistry applies the ideal gas concept in referring to hypothetic gases composed of non-interacting point particles that move randomly. This approach is a simplified way of studying gases, and allows us to predict their behavior.

Boyle´s Law states the inversely proportional relationship between the pressure and volume of an ideal gas at constant temperature. Therefore, the product of pressure and the volume is represented by a constant (k).

$$PV = k$$

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Introduction and theory

When we keep the temperature constant inside a closed system, with a fixed amount of gas, the before and after volume and pressure are represented by the following equation:

Where:

$$P_1V_1 = P_2V_2$$

P = initial pressure
V = initial volume
P = final pressure
V = final volume

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Introduction and theory

Now students are encouraged to raise a hypothesis which must be tested with an experiment.

?

If you have a confined gas inside a syringe and decrease the volume, how does the internal pressure change?

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Activity description

Students will investigate the effect of volume changes on the pressure inside a syringe with a fixed amount of air at constant temperature. They will measure the air pressure and then proceed to build a graph plotting their results in order to analyze them.

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Resources and materials

1. Labdisc
2. Syringe
3. Plastic tube

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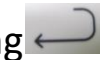
Using the Labdisc

Labdisc configuration

To collect measurements with the Labdisc and thermocouple sensor, the Labdisc must be configured according to the following steps:

1. Turn on the Labdisc  .
2. Press  and select "SETUP" by pressing  .
3. Now select "SET SENSORS" by pressing  and choose "air pressure".
4. On the setup menu, press  and select "SAMPLING RATE" with  .

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Using the Labdisc

5. Select "MANUAL" with  and then press  three times to go back to the measurements and run the Labdisc pressing  .

6. Once you have finished measuring, stop the Labdisc by pressing  (you will see the instruction "press SCROLL key to STOP") and press  .

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Experiment

1. Connect the syringe tip with the transparent head of the plastic tube and fill the syringe with air until 60 mL. Connect the plastic tube to the air pressure sensor screwing in the white head. Once completed start the measurements.

2. Register the value of the pressure data volume of 60 mL. Then decrease the volume by 10 mL. by gently pushing the plunger. Wait until the measurements stabilize and register the pressure once again.

3. Measure the pressure at points of 60, 50, 40 and 30 mL. of air inside the syringe and then stop the Labdisc.

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Results and analysis

1. Connect the Labdisc to the computer using the USB communication cable or via the Bluetooth wireless communication channel.

2. In the top menu click the  button and select the  button. Select the last experiment of the list.

3. Observe the graph displayed on the screen and write notes on the graph by pressing  , specifying your observations according to the moment you registered the data.

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Results and analysis

4. Press the  button, save the data on the computer and export to Excel.

5. Add a third column with the air volume (in mL.) recorded at each measurement.

6. Multiply the air pressure with the volume in each case and compare the values.

	A	B	C	D
1	Time [s]	Air pressure [kPa]	Volum [ml]	Px V
2	0	101.1	60	6066
3	1	123.2	50	6160
4	2	152	40	6080
5	3	195.6	30	5868

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Results and analysis

Were there differences between what you expected and your actual results?

What happens with the air pressure when you decrease the volume?

Can you find any relation between the pressure and the volume of a gas in a closed container?

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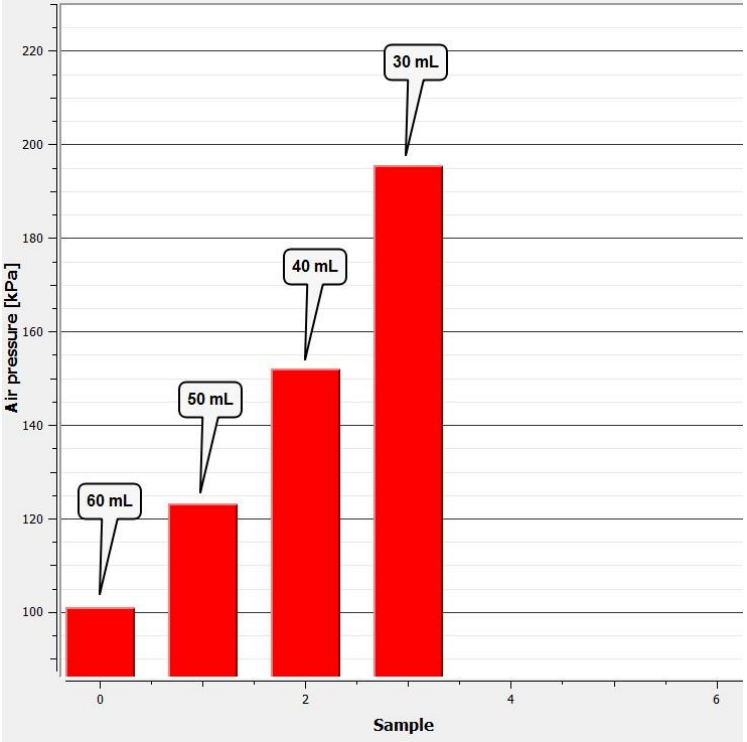
Results and analysis

The graph below should be similar to the one the students came up with:



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Conclusion

Observe the relation between pressure and volume, as well as the characteristics of the values obtained in each case?

Students should observe and compare the values obtained and indicate that they are relatively constant; which is explained by the Boyle´s Law statement.

What kind of pressure variation is observed when the plunger is down?

Students should understand that when the plunger is down the gas volume is decreased and therefore the pressure increases.

What happens with the closed system´s conditions when its volume increases?

Students should establish that lifting the plunger raises the volume inside the syringe, therefore lowering the pressure. This happens because a fixed number of air particles exert force against the sides of the container which now has increased the available space for them.

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Conclusion

If you consider the Boyle´s Law statement and observe the multiple of pressure and volume in each case, how do you explain the variation between them?

Students should indicate certain variations that could influence the results, such as the pulse of the person who was measuring, the accuracy of the syringe, etc.

What is the relationship between the volume and the air pressure of a gas in a closed container?

Students should establish an inverse proportionality between the air pressure and volume. When the volume decreases, the pressure increases and vice versa.

What do you think happens on a molecular level, that allows these pressure variations to occur?

Students should relate the air pressure to the molecular movements of the air particles. The particles collide with other particles and with the walls of the container. At an increased volume there are fewer particles colliding in the same wall surface area, and therefore the pressure drops. If you reduce the space, the particles will collide more often, causing the pressure to rise.

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Conclusion

Students should reach following conclusions:

There is an inverse relationship between the volume and the pressure inside a closed container. This relationship is expressed by the Boyle-Marriot Law which tells us that at constant temperature the volume is inversely proportional to the pressure, and the product of both variables is constant. We can conclude from this that when you increase the volume, the pressure decreases; and when you decrease the volume the pressure increases.

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Activities for further application

Consider an ideal gas at an initial pressure P1 of 1 [atm] and a volume V1 of 30 [l]. What is the final volume if the pressure increases to 2.5 atm? (T = constant)

Students should put the Boyle-Marriot Law into practice and calculate the final volume V2 of the ideal gas. The correct answer is 12 liters.

How would the pressure of a confined gas inside of a syringe vary, if we try to compress it as much as possible?

Students should analyze the situation and understand that if we compress the air we reduce the volume, raising the pressure because of the inverse relationship of both variables.

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Activities for further application

What is the purpose of considering ideal as opposed to real gases?

Students should understand that a simple conceptual approach helps us to study and calculate the parameters of real gases behavior.

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