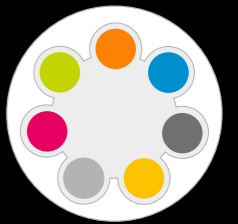


# Applied Sciences

## ▶ Boyle's Law

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





# Applied Sciences

## Boyle's Law

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

### Objective

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# Applied Sciences

## Boyle's Law

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

### 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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## ▶ Boyle's Law

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### Introduction and theory



The aim of the introduction is to focus students on the lesson subject by refreshing acquired knowledge and asking questions which encourage research development. Key concepts from the theoretical framework, applied by the students during the lesson, are taught.

### Introduction

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.



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

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## Boyle's Law

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### Introduction and theory



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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## ▶ Boyle's Law

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### Introduction and theory



### Theoretical

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

$$P = \frac{F}{A}$$

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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## Boyle's Law

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

### 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:

$$P_1 \cdot V_1 = P_2 \cdot V_2$$

Where

$P_1$  = initial pressure

$V_1$  = initial volume

$P_2$  = final pressure

$V_2$  = final volume

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## Boyle's Law

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

### 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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## Boyle's Law

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

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

### Resources and materials



- 1 Labdisc
- 2 Luer-lock syringe 60 mL.
- 3 Plastic tube



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

### Using the Labdisc



#### a. Using the Labdisc

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

- 1 Turn on the Labdisc pressing 
- 2 Press , and select "SETUP" by pressing 
- 3 Now select option "SET SENSORS" by pressing 
- 4 Select only the air pressure sensor and then press 
- 5 Once you have done that, you will be back at setup, press  and select "SAMPLING RATE" with 
- 6 Select "MANUAL" with  and then press 
- 7 Press  and select "NUMBER OF SAMPLES" with 







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

### Using the Labdisc



- 8 Select "MANUAL" with  and then press 
- 9 To go back to the measurements press  two times
- 10 Then press  to start measuring
- 11 Once you are finished measuring stop the Labdisc by pressing  (you will see the instruction "Press SCROLL key to STOP") and press 

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### Experiment



The following steps explain how to perform the 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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## ▶ Boyle's Law

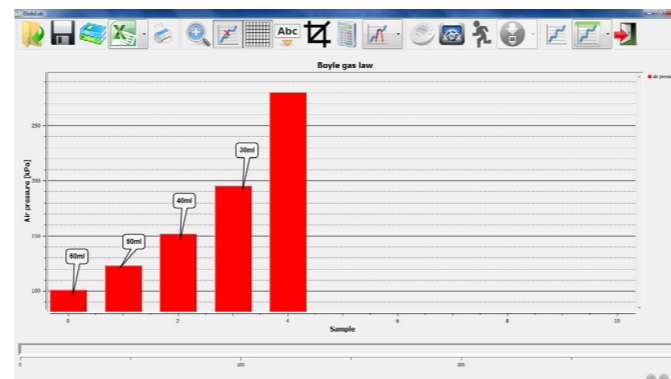
Measuring air pressure in a closed container while verifying the relations between air pressure and volume

## Results and analysis



The following steps explain how to analyze the experiment results.

- 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
- 3 Select the last experiment of the list
- 4 Observe the graph displayed on the screen
- 5 Press the  button and write notes on the graph specifying your observations according to the moment you registered the data




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## Results and analysis



- 6 Press the  button, save the data on the computer and export to Excel
- 7 Add a third column with the air volume (in mL) recorded at each measurement
- 8 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

# Applied Sciences

## Boyle's Law

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

### 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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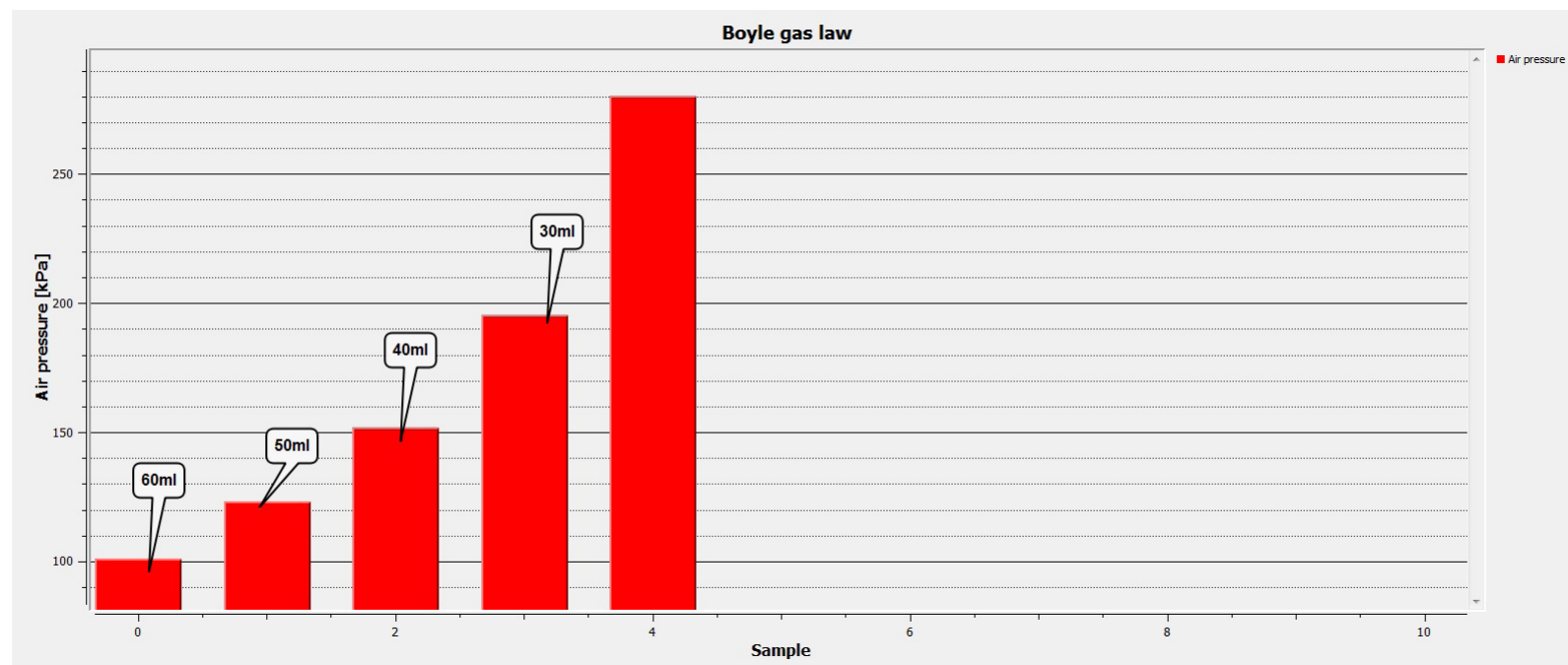
## ▶ Boyle's Law

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## Results and analysis



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



# Applied Sciences

## ▶ Boyle's Law

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

## Conclusions



Following are some questions and answers which should be developed by students in order to elaborate on their conclusions.

?

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.

?

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.

?

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

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

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## ▶ Boyle's Law

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

### Conclusions



?

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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## ▶ Boyle's Law

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

## Conclusions



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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## ▶ Boyle's Law

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

Activities for further application



The aim of this section is for students to extrapolate the acquired knowledge during this class through its application in different contexts and situations. Furthermore, it is intended that students question and present possible explanations to the experimentally observed phenomena.

Further questions:

?

Consider an ideal gas at an initial pressure  $P_1$  of 1 atmosphere and a volume  $V_1$  of 30 liters. What is the final volume if the pressure  $P_2$  increases to 2.5 atm? Consider the temperature to be constant.

Students should put the Boyle-Marriot Law into practice and calculate the final volume  $V_2$  of the ideal gas. The correct answer is 12 liters.

# Applied Sciences

## Boyle's Law

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

**Activities for further application**



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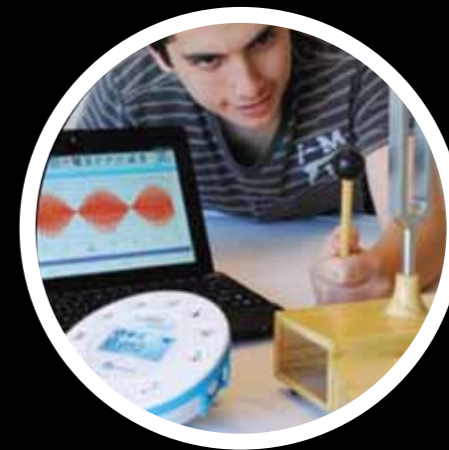
What is the purpose of considering ideal as opposed to real gases?

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

?

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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