

NSTA 2024  
Denver, CO

# Introduction to Vernier: The Basics for Beginners

## Experiments

### A Hot Hand

- Go Direct Temperature Probe

### Ramps as Machines

- Go Direct Sensor Cart

### Boyle's Law: Pressure-Volume Relationships

- Go Direct Gas Pressure Sensor

## Workshop Presenter

Dave Carter

[support@vernier.com](mailto:support@vernier.com)



Vernier Science Education • 888-VERNIER (888-837-6437)  
[info@vernier.com](mailto:info@vernier.com) • [www.vernier.com](http://www.vernier.com)





# A Hot Hand

You will measure the temperature of the palm of your hand and the palm temperatures of your teammates in this experiment. In the process, you will learn how to use the data-collection equipment you will be using throughout the school year. You will also get to know your teammates better.

## OBJECTIVES

- Use a temperature probe to measure temperature.
- Calculate temperature averages.
- Compare results.

## MATERIALS

Chromebook, computer, **or** mobile device  
Graphical Analysis app  
Go Direct Temperature  
beaker  
water  
paper towel



## PROCEDURE

1. Launch Graphical Analysis. Connect the Temperature Probe to your Chromebook, computer, or mobile device.
2. Click or tap Mode to open Data Collection Settings. Set End Collection to 60 s. Click or tap Done.
3. Measure the temperature of the palm of your hand.
  - a. Click or tap Collect to start data collection.
  - b. Pick up the Temperature Probe and hold its tip in the palm of your hand as shown in Figure 1. Data collection will end when 60 seconds have gone by.
4. Record your highest temperature.
  - a. When data collection is complete, a graph of temperature *vs.* time will be displayed. To examine the data pairs on the displayed graph, click or tap any data point. As you tap each data point, the time and temperature values of the point are displayed. **Note:** You can also adjust the Examine line by dragging the line.
  - b. Record your highest temperature.

## ***A Hot Hand***

5. Prepare the Temperature Probe for the next run.
  - a. Cool the Temperature Probe by placing it into a beaker of room-temperature water until its temperature reaches the temperature of the water. The temperature of the probe is displayed in a meter on the screen.
  - b. Use a paper towel to dry the probe. Be careful not to warm the probe as you dry it.
6. Repeat Steps 3–5 for each person in your group.

### **DATA**

Student name	Maximum temperature (°C)
Group average	

### **PROCESSING THE DATA**

1. Calculate the group average for the highest temperatures. Record the result in the data table.
2. How did the maximum temperature for each person compare?
3. Who had the “hottest hand”?

### **EXTENSION**

Determine the class average for maximum temperature.

# Ramps as Machines

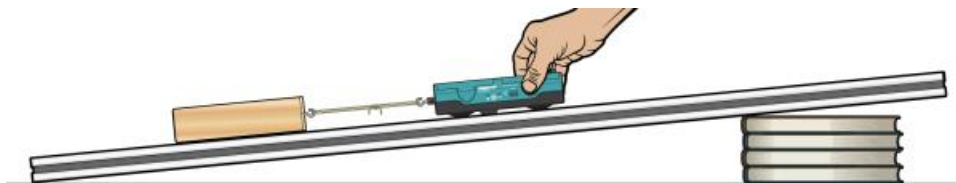
A ramp (also known as an inclined plane) is a slanted surface used to raise or lower objects. The sloping floor of a theater, a road over a mountain, and a ramp into a building are examples of ramps. In this experiment, you will use the force sensor built into a Sensor Cart to measure the force needed to lift an object and the force needed to pull the same object up a ramp. You will then calculate and compare work done in raising the object to the same height by lifting it and pulling it up a ramp.

## OBJECTIVES

- Measure force.
- Compare forces.
- Calculate work and efficiency.
- Make conclusions using the results of the experiment.

## MATERIALS

Chromebook, computer, **or** mobile device  
Graphical Analysis app  
Go Direct Sensor Cart  
smooth board (at least 0.5 m long)  
wooden block with a hook  
books  
metric ruler  
loop of string **or** paper clip




*Figure 1*

## PROCEDURE

### Part I Using a ramp

1. Set up a stack of books as shown in Figure 1.

## ***Ramps as Machines***

2. Get a board and set up a ramp as shown in Figure 1. Measure the length of the board (in meters) and record this value in the data table. Measure and record the height of ramp (in meters).
3. Get a wooden block with a hook on one end. Either make a loop of string or use a paper clip to attach the wooden block to your Go Direct Sensor Cart.
4. Launch Graphical Analysis. Connect the Sensor Cart to your Chromebook, computer, or mobile device. Click or tap Sensor Channels, deselect Position, and select Force. Click or tap Done.
5. Click or tap Mode to open data collection settings. Change End Collection to 3 seconds. Click or tap done.
6. To zero the force sensor, hold the cart on the ramp with nothing attached to the hook and the hook pointing down on the ramp. Click or tap the Force meter and choose Zero.
7. Slowly pull the wooden block up the ramp using the cart. Once the wooden block is moving at a steady rate, click or tap Collect to start data collection.
8. Determine the mean (average) force (in N).
  - a. Click or tap Graph Tools, , and choose View Statistics.
  - b. Record the mean force.

### **Part II Without a ramp**

9. Now determine the force needed to lift the wooden block. First, hold the cart vertically with the hook down and nothing attached to the hook. Zero the force sensor. Then, hang the block from the cart and slowly lift the block straight up at a constant speed. Once the wooden block is moving at a steady rate, click or tap Collect to start data collection.
10. Record the average value of the force required to lift the block straight up.

### **DATA TABLE**

Length of ramp (m)	
Height of ramp (m)	
Force (average) to pull the block up the ramp (N)	
Force (average) to lift the block (N)	

## PROCESSING THE DATA

- Two smooth wooden blocks can slide over each other with comparatively little friction. In a case such as this, compare the amount of force required to pull the block along the ramp compared to the amount required to lift the block straight up. Does it take more or less force to move the block using the ramp?
- A formula for calculating work is

$$W = F \times d$$

where  $W$  = work (in N•m),  $F$  = force (in N), and  $d$  = distance (in m). Use this formula to calculate the work that would be required to pull the block along the complete length of the ramp. Here,  $F$  = the average force needed to pull the block up the ramp, and  $d$  = the **length** of the ramp.

- Calculate the work that would be required to lift the block straight up (without using the ramp) a distance equal to the height of the ramp. Here,  $F$  = the average force needed to lift the block and  $d$  = the **height** of the ramp.
- Does it take more or less work to move the block using the ramp? Does it take more or less force to move the block using the ramp?
- A formula for calculating the efficiency of a machine

$$\text{efficiency} = \frac{\text{work output}}{\text{work input}} \times 100\%$$

Use this formula to calculate the efficiency of the ramp. Here, work output = the work done lifting the block, and work input = the work done pulling the block up the ramp.

- What causes the difference between the work needed to pull the block up the ramp and the work to lift it to the same height? Discuss ways to decrease this difference.

## EXTENSIONS

- Study how changing the slant of the ramp changes the force needed to pull the block up the ramp.
- Design an experiment to study your answer to Question 6.
- Determine the actual mechanical advantage ( $AMA$ ) of your ramp. The actual mechanical advantage is defined to be:

$$AMA = \frac{\text{force used to lift block straight up}}{\text{force used to pull block up ramp}}$$

If there is not too much friction between the block and the ramp, the mechanical advantage should be a number greater than one.

- Repeat the experiment using two surfaces with a great deal of friction. For example, there will be a lot of friction between a smooth surface and a soft rubbery surface. Many calculators come with rubbery feet that produce a lot of friction on smooth surfaces. If the two surfaces have a lot of friction, does the ramp produce a mechanical disadvantage?



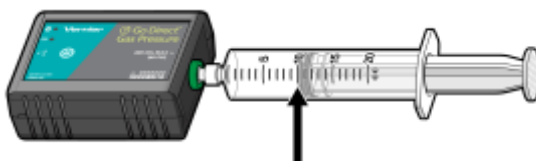


# Boyle's Law: Pressure-Volume Relationship in Gases

The primary objective of this experiment is to determine the relationship between the pressure and volume of a confined gas. The gas we use will be air, and it will be confined in a syringe connected to a gas pressure sensor (see Figure 1). When the volume of the syringe is changed by moving the piston, a change occurs in the pressure exerted by the confined gas. This pressure change will be monitored using a gas pressure sensor. It is assumed that temperature will be constant throughout the experiment. Pressure and volume data pairs will be collected during this experiment and then analyzed. From the data and graph, you should be able to determine what kind of mathematical relationship exists between the pressure and volume of the confined gas. Historically, this relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's law.

## 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 pressure and volume of the gas.
- Describe the relationship between gas pressure and volume in a mathematical equation.
- Use the results to predict the pressure at other volumes.



*Figure 1*

## MATERIALS

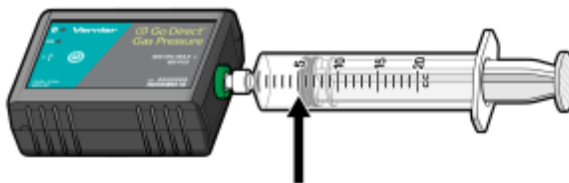
Chromebook, computer, **or** mobile device  
Graphical Analysis app  
Go Direct Gas Pressure  
20 mL gas syringe

## PROCEDURE

1. Prepare the data-collection equipment and an air sample for data collection.
  - a. Launch Graphical Analysis. Connect the Gas Pressure Sensor to your Chromebook, computer, or mobile device.
  - b. With the 20 mL syringe disconnected from the Gas Pressure Sensor, move the piston of the syringe until the front edge of the inside black ring (indicated by the arrow in Figure 1) is positioned at the 10.0 mL mark.
  - c. Attach the 20 mL syringe to the valve of the Gas Pressure Sensor.
2. Set up the data-collection mode.
  - a. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
  - b. Enter **Volume** as the Event Name and **mL** as the Units. Click or tap Done.
3. To obtain the best data possible, you will need to correct the volume readings from the syringe. Look at the syringe; its scale reports its own internal volume. However, that volume is not the total volume of trapped air in your system since there is a little bit of space inside the pressure sensor.



To account for the extra volume in the system, you will need to add 0.8 mL to your syringe readings. For example, with a 5.0 mL syringe volume, the total volume would be 5.8 mL. It is this total volume that you will need for the analysis.

4. You are now ready to collect pressure and volume data. It is easiest if one person takes care of the gas syringe and another enters volumes.
  - a. Click or tap Collect to start data collection.
  - b. Move the piston so the front edge of the inside black ring (see Figure 2) is positioned at the 5.0 mL line on the syringe. Hold the piston firmly in this position until the pressure value displayed on the screen stabilizes.
  - c. Click or tap Keep and enter **5.8**, the gas volume (in mL). Remember, you are adding 0.8 mL to the volume of the syringe for the total volume. Click or tap Keep Point to store this pressure-volume data pair.



*Figure 2*


- d. Continue this procedure using syringe volumes of 10.0, 12.5, 15.0, 17.5, and 20.0 mL.
  - e. Click or tap Stop to stop data collection.
5. When data collection is complete, a graph of pressure vs. volume will be displayed. To examine the data pairs on the displayed graph, tap any data point. As you tap each data point, the pressure and volume values are displayed to the right of the graph. Record the pressure and volume data values in your data table.

6. Based on the graph of pressure vs. volume, decide what kind of mathematical relationship exists between these two variables, direct or inverse. To see if you made the right choice:
  - a. Click or tap Graph Tools, , and choose Apply Curve Fit.
  - b. Select Power as the curve fit and Dismiss the Curve Fit box. The curve fit statistics are displayed for the equation in the form
 
$$y = ax^b$$
 where  $x$  is volume,  $y$  is pressure,  $a$  is a proportionality constant, and  $b$  is the exponent of  $x$  (volume) in this equation. **Note:** The relationship between pressure and volume can be determined from the value and sign of the exponent,  $b$ .
  - c. If you have correctly determined the mathematical relationship, the regression line should very nearly fit the points on the graph (that is, pass through or near the plotted points).
  - d. Rescale the axes on your graph by clicking or tapping Graph Tools, . Choose Edit Graph Options and set the x-axis to display 0 to 25 mL and the y-axis to display 0 to 300 kPa. Dismiss the Graph Options box.
  - e. (optional) Export, download, or print the graph with the curve fit displayed.
7. With the best-fit curve still displayed, proceed directly to the Processing the Data section.

## DATA AND CALCULATIONS

Volume (mL)	Pressure (kPa)	Constant, $k$ (P / V or P • V)



## PROCESSING THE DATA

1. With the best-fit curve still displayed, click or tap Graph Tools, , and turn on Interpolate. Dismiss the Graph Tools box and click the graph to interpolate. Move along the regression line until the volume value is 5.0 mL. Note the corresponding pressure value. Now move to the point where the volume value is doubled (10.0 mL). What does your data show happens to the pressure when the volume is *doubled*? Show the pressure values in your answer.


## Boyle's Law: Pressure-Volume Relationship in Gases

- Using the same technique as in Question 1, what does your data show happens to the pressure if the volume is *halved* from 20.0 mL to 10.0 mL? Show the pressure values in your answer.
- Using the same technique as in Question 1, what does your data show happens to the pressure if the volume is *tripled* from 5.0 mL to 15.0 mL? Show the pressure values in your answer.
- From your answers to the first three questions *and* the shape of the curve in the plot of pressure *vs.* volume, do you think the relationship between the pressure and volume of a confined gas is direct or inverse? Explain your answer.
- Based on your data, what would you expect the pressure to be if the volume of the syringe was increased to 40.0 mL? Explain or show work to support your answer.
- Based on your data, what would you expect the pressure  $P$  to be if the volume of the syringe was decreased to 2.5 mL? Explain or show work to support your answer.
- What experimental factors are assumed to be constant in this experiment?
- 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,  $k = P \cdot V$ . Based on your answer to Question 4, choose one of these formulas and calculate  $k$  for the seven ordered pairs in your data table (divide or multiply the  $P$  and  $V$  values). Show the answers in the third column of the Data and Calculations table.
- How *constant* were the values for  $k$  you obtained in Question 8? Good data may show some minor variation, but the values for  $k$  should be relatively constant.
- Using  $P$ ,  $V$ , and  $k$ , write an equation representing Boyle's law. Write a verbal statement that correctly expresses Boyle's law.

## EXTENSION

- To confirm that an inverse relationship exists between pressure and volume, a graph of pressure *vs.* *reciprocal of volume* ( $1/\text{volume}$ ) may also be plotted. To do this, it is necessary to create a new column of data, reciprocal of volume, based on your original volume data:
  - Click or tap More Options, , in the Volume column header in the table. Choose Add Calculated Column.
  - Enter **1/volume** as the Name and **1/mL** as the Units.
  - Click or tap Insert Expression and choose A/X as the expression.
  - Enter **1** as Parameter A and select Volume as the Column.
  - Click or tap Apply.
- Plot a best-fit regression line on your graph of pressure *vs.*  $1/\text{volume}$ :
  - Click or tap Graph Tools, , and choose Edit Graph Options.
  - Enter **0** as the value for both the Left value for the x-axis and the Bottom value for the y-axis.
  - Dismiss the Graph Options box. Your graph should now include the origin (0,0).

## *Boyle's Law: Pressure-Volume Relationship in Gases*

- d. Click or tap Graph Tools, , and choose Apply Curve Fit.
- e. Select Linear as the curve fit and Dismiss the Curve Fit box. The linear-regression statistics are displayed in the form:

$$y = mx + b$$

where  $x$  is  $1/\text{volume}$ ,  $y$  is pressure,  $m$  is a proportionality constant, and  $b$  is the  $y$ -intercept.

- f. If the relationship between  $P$  and  $V$  is an inverse relationship, the graph of pressure vs.  $1/\text{volume}$  should be direct; that is, the curve should be linear and pass through (or near) the origin. Examine your graph to see if this is true for your data.