

How Does Atmospheric Pressure Vary?
Measuring Atmospheric Pressure At
Different Altitudes Above Sea Level
(Teacher's Guide)

OVERVIEW

Students will evaluate air pressure variations in different altitudes on a field trip. They will use a barometer (or air pressure sensor) and GPS to register atmospheric pressure and altitude data at different points along the trip. Based on the results, students will relate both variables with their hypothesis.

MATERIALS NEEDED

Ward's DataHub
USB connector cable*

** – The USB connector cable is not needed if you are using a Bluetooth enabled device.*

NUMBER OF USES

This demonstration can be performed repeatedly.

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		

Dimension 3 Core Concepts	Discipline	Core Idea Focus
	Engineering, Technology, and Applications of Science	
		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
	MS.PS-FM: Forces and Motion	HS.PS-FM: Forces and Motion

NATIONAL SCIENCE EDUCATION STANDARDS © 2002

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

✓ Indicates Standards Covered in Activity

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 study atmospheric pressure variations, as higher altitudes are reached, in order to create a hypothesis. The hypothesis will be tested using the Ward's DataHub air pressure and GPS sensors.

Time Requirement:

60 - 90 minutes

VOCABULARY

Altitude: The height of an object or point in relation to sea level or ground level.

Atmospheric Pressure: Pressure caused by air.

Barometer: An instrument measuring atmospheric pressure.

Density: The degree of compactness of a substance.

Force: Simply a push or pull.

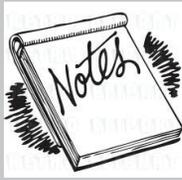
GPS: Global Positioning System, an accurate worldwide navigational and surveying facility based on the reception of signals from an array of orbiting satellites.

Gravity: The force that attracts a body toward the center of the earth, or toward any other physical body having mass.

Magdeburg: A city in Germany where a scientist first demonstrated the large amount of air pressure that we all live in. It was done by removing the air from between two large hemispheres that were sealed air tight and then two teams of horses were engaged to try to pull them apart. Having not been able to do it with the horses, the scientist then walked over to the hemispheres, opened a valve to let air back into the cavity between the hemispheres and they fell apart.

Gas Pressure: The number of pounds per square inch exerted by gaseous molecules.

Vacuum: A space where there is no pressure, usually caused by the lack of any molecules even air molecules. A totally empty space is another way of describing it.



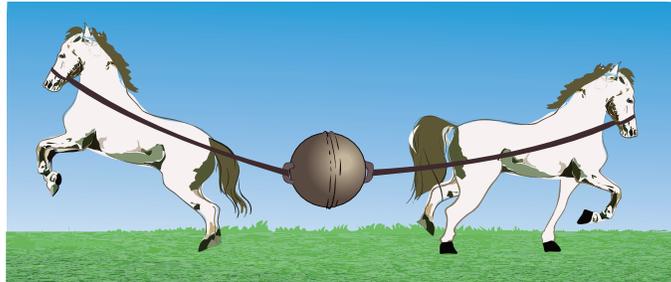
Teacher Notes

Magdeburg hemispheres can be demonstrated by using a suction cup on a flat surface such as a mirror or table top. The suction cup stays in place because all of the air has been removed between the two objects.



INTRODUCTION

A 17th century German lawyer, interested in mathematics and engineering, Otto von Guericke (1602-1686) conducted various experiments in vacuum systems.



One of his most dramatic experiments was made at Magdeburg in 1657, known as the “Magdeburg hemispheres”. Guericke used a vacuum pump to suck the air from inside a hollow sphere. This sphere was formed by two identical bronze hemispheres, which had been perfectly fit together due to the vacuum. An eight horse team was tied to each hemisphere, and then the two teams tried to pull apart and divide the sphere. Despite the “sixteen horse-power”, the hemispheres could not be separated!



His experiment showed the power of air pressure that kept the hemispheres together.

- **How would you explain what happened with the “Magdeburg hemispheres”?**
- **What is the relationship between the vacuum inside the sphere and the air pressure outside the sphere?**

Carry out the experiment with your class so that at the end, students will be able to answer the following question:

- **How does atmospheric pressure vary in response to changes in altitude?**



DID YOU KNOW?

Although air is light, there is so much of it that air can exert a huge pressure at ground level.

It pushes in all directions at ground level with a force of over 1 kg per square cm; that is equivalent of an elephant standing on a coffee table.

BACKGROUND

Atmospheric pressure is defined as the pressure exerted by atmospheric air on the surface area of Earth, due to the force of gravitational attraction. Therefore, it is related to the weight of the air column on the Earth's surface. However, air is a gas mixture and expands to fill the entire volume available, exerting pressure, not only on the ground, but in all directions.

Normal atmospheric pressure is equal to the pressure exerted by a mercury column at a sea level of 76 cm, 0 °C. We call this value atmosphere (atm.) and use it as a relative unit for pressure. Besides atmospheres, other pressure units are the mercury millimeters (mmHg), millibars (mbar) and kilopascals (kPa).

So we have:

$$1 \text{ atm} = 760 \text{ mmHg} = 1013.3 \text{ mbar} = 101.32 \text{ kPa}$$

Let's try a simple activity, emphasizing the variations in atmospheric air pressure:

Take a glass of water and add two spoonfuls of earth, then stir and wait five minutes. Do you notice any changes in the water? Where is the earth now?

Gravity force attracts air molecules toward the Earth. It is therefore logical to assume that closer to the Earth's surface there are more air particles than found at higher altitudes. This leads to a greater particle density as we approach the Earth's surface, causing the existence of layers or stratus. Lower layers receive pressure from upper layers, creating yet further air density difference. This is similar to what we observed when we stirred earth into a glass of water. We found a greater concentration of earth next to the bottom of the glass, and therefore in the water and closer to the surface of the water, the solution was thinner than the suspension at the bottom.

We can therefore conclude that as we approach sea level, the greater the air density and the greater the atmospheric pressure. As we gain altitude the amount of air particles per unit area decreases. Therefore, the air is less dense and the pressure will decrease.

At this point, encourage students to formulate a hypothesis to test as part of this activity. Students may find it helpful to formulate their hypothesis as an answer to the following questions:

- **Suppose you measure atmospheric pressure at the place you are right now. Do you think you could obtain your altitude? Assuming that you could, can you guess what altitude over sea level you are?**

CONNECTING THE WARD'S DATAHUB TO A COMPUTER

If you are using a Bluetooth communication device:

Right-click on the Bluetooth icon in the lower right corner of the screen and select the Ward's DataHub you are using. The icon will change from gray to blue, as shown at right, indicating that the Ward's DataHub and the computer are now connected via Bluetooth.

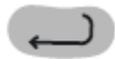


If you are using a USB communication device:

In order to use USB communication, connect the Ward's DataHub and the computer with the USB cable supplied. Click on the USB icon at the lower right corner of the screen. This icon will change from gray to blue, as shown at right, indicating that the Ward's DataHub is connected to the computer via USB.



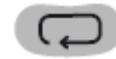
USING THE WARD'S DATAHUB



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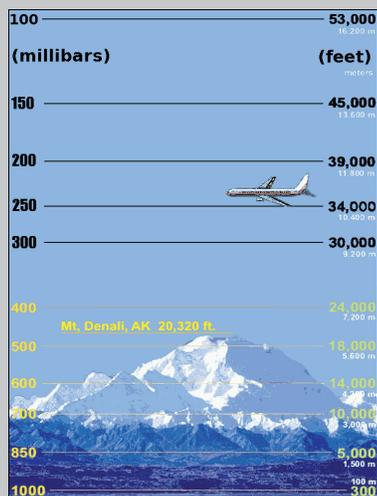
To collect measurements with the Ward's DataHub, it must first be configured as follows:

1. Turn on the Ward's DataHub by pressing the On/Off/Esc key.		8. Press the On/Off/Esc key to return to the setup menu.	
2. Go to setup by using the Scroll key then select Setup by pressing the Select key.	 then 	9. Press the Scroll key to highlight the Number of Samples and then press the Select Key.	 then
3. Select the Set Sensors option by pressing the Select key.		10. Press the Scroll key until "1000" is highlighted, then press the Select key.	 then
4. If any sensor(s) appear on the screen, press the key representing that sensor to deactivate it. Press the Humidity/GPS Sensor key Twice. Also press the Air Pressure/Barometer Sensor key Once.	 x 2 then 	11. Press the On/Off/Esc key Three times to return to the main operating screen.	 x 3
5. Press the On/Off/Esc key once to return to the setup menu.		12. Press the Select key to start measuring. (You are collecting data when there is an icon of a Runner in the upper left hand corner of the screen.)	
6. Press the Scroll key to highlight the Sampling Rate and then press the Select Key	 then 	13. Once you have finished measuring, stop the Ward's DataHub by pressing the Select key, followed by the Scroll key.	 then
7. Press the Scroll key until "1/min" is highlighted, then press the Select key.	 then 		



DID YOU KNOW?

Barometric air pressure at sea level is approximately 15 pounds per square inch, and the weight of this air spread over 1 square foot is approximately 2000 pounds of pressure. At 18,000 feet, the barometric pressure is 7.5 pounds per square inch, and 1000 pounds per square foot. The higher the air is above sea level, the less it weighs, causing a decrease in the amount of pressure exerted against a person.



ACTIVITY

1. Define a path to ensure a significant elevation difference between the end and the start of the trail.
2. At intervals during the trip, measure the air pressure, especially at each sensible altitude difference.
3. Once you have finished measuring, turn the Ward's DataHub off.

RESULTS AND ANALYSIS

1. Connect the Ward's DataHub to the computer using the USB communication cable or via the Bluetooth wireless communication channel.
2. In the top menu, click .
3. Select the last experiment on the list.
4. Observe the graph displayed on the screen.
5. Press  and write notes on the graph, specifying your observations according to the moment you registered the data.
6. Right-click the y-axis and set the minimum and maximum values according to your measurements. Round your minimum value down and your maximum value up, and enter these numbers into "minimum" and "maximum".
7. To see the map, make sure your computer is connected to the Internet.
8. Click  which is in the top-right corner of the Ward's DataHub screen. Then click .
9. In the top-right corner of the map, you'll see the words "map" and "satellite".
 - If you click on the map, you'll see only street names.
 - If you click on satellite, you'll see only the satellite image.
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DID YOU KNOW?

The first mercury barometer was developed by Evangelista Torricelli, a student of Galileo Galilei, in 1643. The design has not changed much since then.

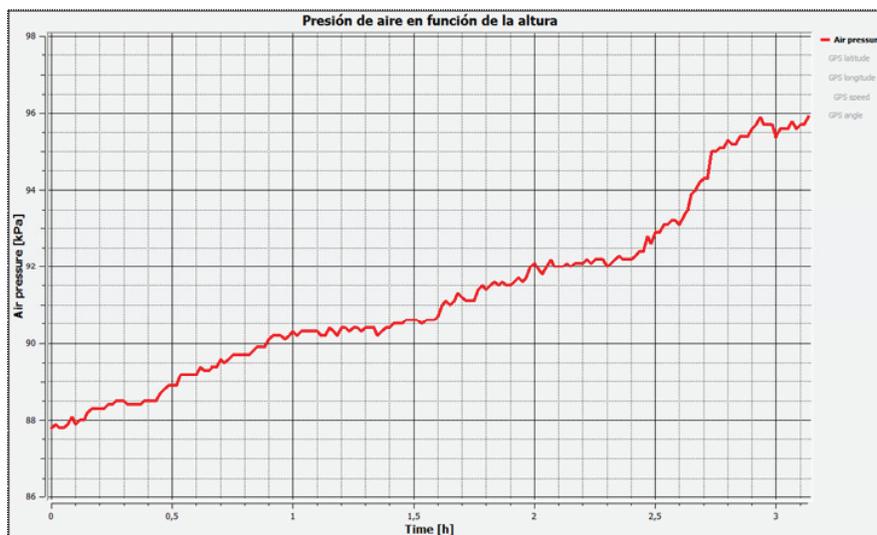


RESULTS AND ANALYSIS

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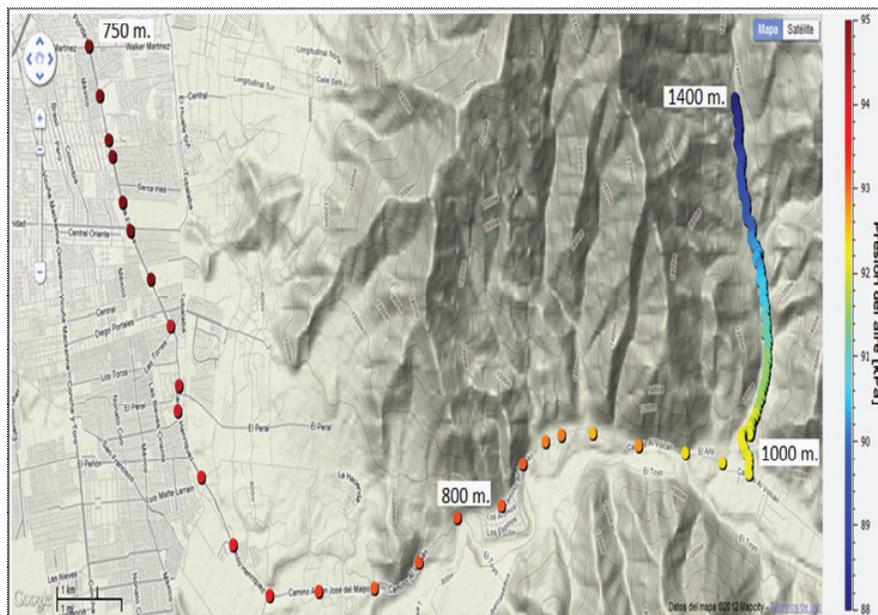
10. If you want to see the exact value of each point, place the mouse's arrow at the desired point on the map and a label with the values will appear.
11. On the top-left corner of the map, you'll see the zoom and the cardinal points.
12. On the right side of the map you'll see the color code scale. Right-click on the scale and use the "set range" to fill in the minimum and maximum air pressure values on the map.
13. To move the map, click on it and move the mouse's arrow.
 - **How do the results relate to your initial hypothesis?**
 - **At which point do you find the maximum atmospheric pressure value? Where did you find the minimum pressure values?**
 - **What is the difference in pressure between the maximum and minimum values? Do you think this is statistically significant?**

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



CONCLUSIONS AND ASSESSMENTS

1. Observe the image on right. Note that the measurement began at 1400 m.a.s.l. on a mountain where the minimum air pressure value was recorded. The altitude decreased during the trip towards the valley, causing an air pressure increase to a maximum of 750 m.a.s.l. (see scale). How would you explain the relationship between atmospheric pressure and altitude?
Explain.



Students should establish that the line graph shows an inverse relationship between altitude and pressure. At an altitude of 1400 meters above sea level the environmental pressure obtained was 88 kPa, and at an altitude of 750 meters above sea level the pressure was 95 kPa, approximately.

2. In your experiment, how did the atmospheric pressure vary in response to changes in altitude?

Students should describe the chart they obtained and explain the differences in air pressure.

3. What could you say about the molecular arrangement of air at different altitudes?

Students should establish that at high altitudes there are fewer molecules per unit volume, and thus less air pressure pressing down on Earth. Therefore, the atmospheric pressure decreases.

4. Is it possible to establish your altitude at a given location by measuring atmospheric pressure?

Students should conclude that this is only possible if you have a point of reference to compare your results with.

5. Write a **concluding** paragraph describing what you observed during the experiment.

Students should reach the following conclusions

Atmospheric pressure has an inverse relationship with altitude, i.e., as you go up in altitude, pressure decreases. We may explain this relationship by remembering that air next to sea level is being pressed down by the upper air layers, and is also attracted by a greater force towards the center of the Earth. The air at sea level is much more dense than air at higher altitudes, and therefore a greater number of particles are exerting pressure on the Earth's surface.



DID YOU KNOW?

Air pressure changes help predict local weather. Rising air pressure usually means fair weather. Falling air pressure generally means stormy weather.



ACTIVITIES FOR FURTHER APPLICATION

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

1. When flying in an airplane, how would you explain the clogged feeling in your ears after the plane reaches altitude?

Students should associate the feeling of fullness or clogging in the ears with a response to altitude changes. At higher altitudes the atmospheric pressure decreases causing a difference in pressure between the inside and outside of the middle ear, which is responsible for the blocked ear sensation.

2. Acute mountain sickness is a disease developed at high altitudes. Some of its symptoms are: Vomiting, dizziness and headache. How could you explain this reaction?

Students should relate the symptoms of sickness to atmospheric pressure at high altitudes. They should establish that pressure changes at high altitudes may be an important factor in developing acute mountain sickness. They should also think of the thinner air at higher altitudes, remembering that there is also less oxygen. Our body is not adapted to a low oxygen environment, and therefore reacts accordingly.

3. According to what you now know, explain how a suction cup works.

Students should point out that when we press a suction cup against a surface, we empty it of air, forming an internal vacuum. The suction cup will remain attached to the surface because of the pressure created by the external air.

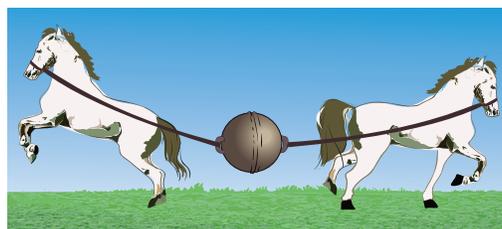
4. If you take a plastic water bottle on a trip to a high altitude, what do you think will happen when you reach the top of the mountain?

Students should conclude that the lower pressure at high altitudes will cause the bottle to expand or even explode because the pressure inside the bottle will be higher than the pressure outside it.

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INTRODUCTION

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- **How would you explain what happened with the "Magdeburg hemispheres"?**
- **What is the relationship between the vacuum inside the sphere and the air pressure outside the sphere?**

After carrying out this experiment, you should be able to answer the following question:

- **How does atmospheric pressure vary in response to changes in altitude?**

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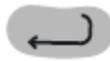


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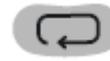
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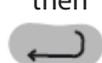
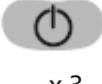


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(continued)

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