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BAROMETRIC PRESSURE

OBJECTIVE

To observe and measure the change in atmospheric pressure with height.

ACTIVITY 1 PREDICTIONS

1. **What is the standard barometric pressure at sea level in atmospheres (atm)? In Pa, kPa, and hPa?**
2. **How do you think barometric pressure changes as you increase your height above sea level?**
3. **Draw a graph of pressure vs. height based on your prediction.**

DISCUSSION

The mathematical formula that describes atmospheric pressure as a function of height is known as the *barometric formula*. Because the pressure at any height depends on the weight of all the air above it, we expect the pressure to decrease as we move upward. The formula for calculating barometric pressure at a specific height is

$$P(z) = P_0 e^{-\alpha z},$$

where $P(z)$ is the barometric pressure at a measured height, P_0 is the barometric pressure at zero height (sea level), z is the measured height and α is a constant of proportionality.

Because the magnitude of height is much, much smaller than the magnitude of barometric pressures in this lab, we can approximate the above equation with the following equation:

$$P(z) = P_0\left(1 - \alpha z\right).$$

W can rearrange the equation to find the change in pressure with z.

$$P(z) = P_0 - P_0 \alpha z.$$
$$P(z) - P_0 = -P_0 \alpha z.$$
$$\Delta P = -P_0 \alpha z.$$

The proportionality constant α is given by $\alpha = mg / kT$**,** where m is the average mass/molecule of air, g is the acceleration of gravity, k is Boltzmann's constant, and T is temperature in Kelvins. The value of α can change depending on the average mass/molecule of air and temperature. However, in our lab, these variables will not change appreciably thus we can calculate α and expect it to remain constant. When we use the following values: $m = 4.80 \times 10^{-26}$ kg, $g = 9.81$ m/s^2, $k = 1.38 \times 10^{-26}$ J/K, and $T = 293$ K, we compute the value of α to be $\boldsymbol{\alpha = 1.16 \times 10^{-4}\ m^{-1}}$**.**

ACTIVITY 2 MEASUREMENT

4. Connect the barometer to the Xplorer™. Change the settings on the barometer to measure in units of hPa. (It will default to mm Hg.)
   1) Press the [√] button. Two arrows will flash on either side of the "in Hg."
   2) Press the [+] button. This will scroll to "hPa."
   3) Press the [√] button again to lock this unit.
5. Carry the barometer, Xplorer™, and meter stick (along with a pencil and paper) to the stairwell of the PSC building.
6. **In the stairwell of the PSC building, measure the distance (height in meters) between floors with the meter stick. Record this measurement.**
7. Stand on the lower floor. Press START on the Xplorer™. (Be sure to keep the Explorer at a fixed position relative to your body.) Walk up the stairs to the next floor. Press STOP on the Xplorer™.
8. Return to the lab. Open the Data Studio icon on your desktop named BAROMETRIC PRESSURE. Connect the Xplorer™ and barometer to the laptop via the USB cable.
9. A window will open asking if you would like to retrieve data. Click RETRIEVE NOW. A graph of barometric pressure vs. time should appear.

ACTIVITY 3 ANALYSIS AND PREDICTION

10. **Determine the initial and final pressures from the graph.**
11. Based on your measurement of height between floors, **estimate the height of the 7th floor of the PSC building above the bottom floor.**
12. Based on your estimate of height, **calculate an estimated barometric pressure on the 7th floor.**
13. Based on your estimate of height, **calculate an estimated barometric pressure at the basement floor.**

ACTIVITY 4 MEASUREMENTS

14. Disconnect the Explorer/barometer unit from the laptop.
15. Carry the Explorer and barometer to the 7th floor of the PSC building. (You may ride the elevator.) Position yourself at the top of the stairwell. (There are 2 stairwells on the Physics side of the building.) Position the barometer at a fixed height on your body (e.g. hold it by your waist.) Press START.
16. Walk all the way down the stairs to the basement. Pause briefly on the landings and on each floor. (Note: The end stairwell closest to Sumwalt, does not begin at the floor level of the basement. Be sure to go down the small flight of stairs to the hallway below.)
17. Press STOP and return to the lab. (You can take the elevator on the way up!)

ACTIVITY 5 ANALYZING THE DATA

18. Connect the Explorer/barometer unit to the laptop computer via the USB cable and retrieve the data. A graph of barometric pressure vs. time will be displayed.
19. **What were the initial and final barometric pressures** (i.e. at the top and at the bottom)?
20. **Explain the flat sections of your graph** where barometric pressure does not change. **Why doesn't pressure change there?**
21. **Was the change in barometric pressure constant between floors?**
22. Try to determine from your graph the location of your barometric pressure data from the first trial. (Activity 2) **Was the pressure data at this location for the second trial the same as the barometric pressure data for the first trial? Should it be?**

ACTIVITY 6 (USE ACTIVITY 5 DATA)

23. **Compare the initial barometric pressure from your graph with your estimated barometric pressure on the 7th floor** (from Activity 3). **Were the measured pressure and calculated pressure the same? Why or why not?**
24. **Compare the final barometric pressure from your graph with your estimated barometric pressure at the basement** (from your calculation in Activity 3.) **Were the measured pressure and calculated pressure the same? Why or why not?**

25. Using the barometric formula and your measured value for height between floors (Activity 2), **calculate the predicted change in barometric pressure** (ΔP) **(a) between floors and (b) between the basement floor and the 7th floor.**

26. **Were these calculated results consistent with your graph?** Using the barometric formula, **calculate the height at each floor** of the PSC building. The formula has been rearranged for you below:

$$z = \frac{P_0 - P(z)}{\alpha P_0}.$$

ACTIVITY 7 (ALTERNATE LOCATION FOR ACTIVITY 4)

27. If weather permits, you may be asked to measure the height of a building other than the PSC using the barometric pressure probe. There are several options such as the Capstone (on campus) the Bank of America and/or the SouthTrust building (downtown).

28. Walk to the building you wish to measure. (Walking there and back will require about 20 to 30 minutes. Walk quickly!)

29. Repeat steps #14 through #17 above. You need not walk down from the top floor as in step 16, just use the elevator. Stop the elevator on several floors so you can have intermediate steps. Be sure to record the floor number to correlate with your data.

ACTIVITY 8 (USE ACTIVITY 7 DATA)

30. **Compute the height of the top floor above the bottom floor.**

31. **Compute the distance between adjacent floors.**

SUMMARY

Upon completion of this lab, you should have accomplished the following objectives:

Understand the barometric formula.

Understand the relationship between barometric pressure and height.

Use the barometric pressure probe and Data Studio to construct a barometric pressure vs. time graph.

Use barometric pressure data and the barometric formula to estimate the height and change in height.

Use measurements of height and the barometric formula to estimate barometric pressure.

Data sheet to hand in. Name _____

BAROMETRIC PRESSURE

WORKSHEET

ACTIVITY 1

USE THE FOLLOWING TABLE TO RECORD YOUR ANSWERS:

What is the barometric pressure at sea level in atmospheres (atm)?

Convert the above pressure (atm) to Pa, kPa, hPa.

Barometric Pressure	atm	Pa	kPa	hPa
Sea Level				

How do you think barometric pressure will change as you increase your height above sea level?

Draw a graph of pressure vs. height based on your prediction.

ACTIVITY 2

What is the height (in meters) between floors in PSC?

ACTIVITY 3

Determine the initial and final pressures from the graph.

	Initial Barometric Pressure (hPa)	Final Barometric Pressure (hPa)
Between Floors		

Based on your measurement of height between floors, estimate the height of the 7th floor of the PSC building.

Height Between Floors (m)	Estimated Height of PSC (m)

Based on your estimate of height, calculate an estimated barometric pressure on the 7th floor and on the basement floor.

Height Between Floors (m)	Estimate Barometric Pressure 7th Floor (hPa)	Estimated Barometric Pressure Basement (hPa)

ACTIVITY 5

What was the initial and final barometric pressure?

Initial Barometric Pressure, top (hPa)	Final Barometric Pressure, bottom (hPa)

Explain the flat sections of your graph where pressure does not change. Why doesn't pressure change at these regular intervals?

Was the change in barometric pressure constant between floors?

Try to determine from your graph the location of your barometric pressure data from the first trial (Activity 2). **Was the pressure data at this location for the second trial the same as the barometric pressure data for the first trial? Should it be?**

ACTIVITY 6

Compare the initial and final barometric pressures from your graph with your estimated barometric pressures on the 7th floor and the basement. Explain any differences.

	Measured pressure at top (from graph)	**Estimated pressure from Activity 3**
Top floor		
Bottom floor		

Using the barometric formula and your measured value for height between floors (Activity 3), calculate the change in barometric pressure (ΔP) between floors and between bottom and top floors

ΔP (Between Floors)	**ΔP (Between Basement and 7th Floor)**

Were these calculated results consistent with your graph?

Using the barometric formula, calculate the height at each floor of the PSC building.

Floor	Base.	1	2	3	4	5	6	7
Height (m)	0							

ACTIVITY 8

Compute the height of the top floor above the bottom floor.

Compute the distance between adjacent floors.