Atmospheric Pressure with Height

(exp. id 20200916-2-v1)

An experiment proposed by:
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Overview

This experiment is meant to study changes in the atmospheric pressure in relation to altitude.
The measurement of pressure can be done using the barometric sensor present in several smartphones.
Thanks to the high sensitivity of such sensors, it is possible to detect very small changes of atmospheric pressure.
Plotting and analysing the collected data encourages discussion at different levels. A linear dependence could lead to an analogy with Stevin's Law of hydrostatics, but a deeper analysis would rather suggest that linearity is a consequence of the narrow range of altitudes where measures can be made. In fact, a more suitable mathematical relation of atmospheric pressure on altitude is a negative exponential law. With this knowledge, measurements can be used to estimate the characteristic constant of the exponential law.

Materials & Requirements

- A smartphone with a pressure sensor
- A tall building (5 floors or more), access to stairs
- A tape measure or a ruler

Making the measurements

This experiment requires a smartphone equipped with a barometer. Not all smartphones have once, hence groups should be formed in which at least one student can perform the pressure measurement. The barometer can be found among the sensors listed by PHYPHOX. Pay attention to the units.

Clicking on the small pulsing triangle on the top right of the display (start button) the sensor starts recording the pressure. You can either visualize the numerical values or a pressure vs. time plot. Choose the numerical visualization during the experiment.

For the experiment, place the smartphone on the landing of the top floor staircase. Wait until the barometer stabilizes.

Since the sensor has a high sensitivity, the last figures of the measures often oscillate across a range of values. One way to deal with this is to consider as reliable only the stable figures of the number in the display, and assign each measurement an uncertainty of 1 unit to the last reliable figure. If possible, consider repeats or measurements with different phones.

Repeat the measurement of the pressure on all landings.

As an estimate of the different heights referred to each pressure, multiply the measurement of the height of one step by the number of steps from one landing to the next one.

General remarks on taking data

Always try to estimate the uncertainties of each measurement properly. Can you spot any source of systematic error? Can you estimate its size?

Before starting any series of measurements, make some tests to train your ability to perform operations seamlessly.

Note the measurements neatly and in a complete way (indicating values, uncertainties and units). Use tables and graphs appropriately.

Pay attention to the measure you are making.

Making and reading the graph

Make a plot of the corresponding values of $Pressure$ vs $height$. Pay attention to the scale on the axes. In a well-done graph, the experimental points should be well spaced on both axes. Make a good choice for the limits (range) of the axes.

The data is likely to look quite linear. Draw (or obtain from the spreadsheet or Python or other ways) the line of best fit and then read on the graph its intercepts; then estimate the slope.

Consider what these data mean.

For the instructor

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1. A simple way to treat the data is to record it on a google spreadsheet. At university level, it would be appropriate to save data in text files, and retrieve the files via python scripts for plotting and fitting.
2. As mentioned in the above section, a discussion on the retrieved data may take place on different levels. In fact, the data plot reveals a linear decreasing trend, which could be considered in analogy to Stevin's Law. A deeper analysis, however, would lead to the unreasonable consequence of a critical height corresponding to a null pressure, or even negative. This consideration rather suggests a negative exponential law. In this perspective the observed linear trend is just due to a scale problem: the height variations that can be reasonably achieved are too small to appreciate the exponential decay. Therefore, the gradient of the graph should be read as the slope of the tangent to the exponential function at the lowest height.
3. A discussion could be made to investigate why Stevin's Law works well with liquids, but fails with atmosphere at large distances.
4. This experiment has been tested with success by a team of high school teachers at a training course at Sapienza Università di Roma

Objectives, Level of deployment, and Duration

1. Primary objective: Enjoying and practicing empirical experiments.
2. Primary objective: Development of scientific investigating skills.
3. Primary objective: Obtaining data that can be plotted and fitted, without requirement of much analysis.
4. Suitable for: high school.
5. Duration: no more than 2 hours of data acquisition, + 1 hour of data plotting, + writing short report.

Further Info Online

Please leave feedback, suggestions, comments, and report on your use of this resource, on the channel that corresponds to this experiment on the Slack workspace "smartphysicslab.slack.com".
Instructors should register on the platform using the form on `smartphysicslab.org` to obtain login invitation to the Slack workspace, and/or to request being added to the mailing list of smartphysicslab.