How Does Pressure Change with Water Depth and with Altitude

Measure the difference of air pressure between the place over your head and the floor. Also measure the hydraulic pressure at different depths using a sensitive pressure sensor.

What you need:

- Vernier BAR-BTA sensitive pressure sensor (barometer)
- Accessories for Vernier PS-ACC pressure sensor
- a tall glass (at least 10 cm) or a graduated cylinder
- a length gauge

Tasks:

Change of air pressure with height

The barometer is very sensitive, so it captures the difference between the air pressure over your head and on the floor. However, this is already the limit of sensitivity of the device. Therefore, some estimations of the mean values around which the pressure oscillates are needed.

1. Connect the barometer to LabQuest. The display shows the actual value of pressure.
2. Put the barometer on the floor and watch the displayed values for a while. They probably "jump" a little around some mean value. This value may have a tendency to increase or decrease over time because pressure relatively rapidly changes

depending on the weather. Estimate the mean value by measuring the pressure for a few seconds.

3. Now raise the sensor over your head and estimate the mean value again.
4. You can put the barometer on the floor and back into the air several times to determine the average pressure difference between the floor and over your head.
5. Measure the height difference (between the floor and over your head).
6. Since air is a fluid (it flows), it is possible to use the equation for the hydraulic pressure in the same way as it is used for water. Estimate the theoretical change in the air pressure between the floor and over your head using this relationship - and compare it with your measurements.

Change of hydraulic pressure with depth

In this measurement, make sure that water never gets into the inner parts of the barometer – the barometer would be damaged. It is therefore necessary to hold the barometer above the water level

1. Attach a tube to the barometer; the tube is a part of Vernier PS-ACC accessories.
2. Before immersing the tube, on the display of LabQuest touch the number of instantaneous pressure value. In the menu that appears, select Zero Sensor. This leads to subtraction of atmospheric pressure, which means that after immersing the tube, the pressure sensor will measure only the pressure increase caused by the hydraulic pressure
3. Do not let water to leak into the barometer through the tube. Always keep the barometer above the water level (water does not flow uphill, but it flows downhill).

4. Immerse the end of the tube into various depths and watch the change in pressure. Since water is approximately a thousand times denser than air, the change of pressure with depth is approximately a thousand times greater than in the previous measurement in the air.

5. Perform the calculation as in the case with air, and compare the theoretical value of the hydraulic pressure with your measurements.

Notes for teachers

The sensitivity of the barometer is 10 Pa, which means that it is able to distinguish the two pressure values if they differ by at least 10 Pa. The inevitable noise of electronic sensors causes the value to fluctuate notably. You can obtain a good estimation of a mean value of pressure by averaging the displayed values (in your mind when viewing the values).

The barometer has a micrometer screw (accessible through a small hole in the body of the sensor). This screw serves for moving the measured pressure up or down. It is used to calibrate the barometer in order to show the pressure corrected to the sea level at a given location. The pressure measured by the barometer does not necessarily accurately correspond to the actual pressure at all times. In the measurements mentioned above, however, we deal with the differences in pressure, so that the absolute value is not essential.

Students have to look up (in memory or in The Handbook of Chemistry and Physics or even on the Internet) the equation for hydraulic pressure.

The height (depth) *h* can be measured by a length gauge. The students probably remember the value of acceleration of gravity. The density of air and water can be found in the Handbook or on the Internet if they do not know it by heart.

A typical height in the first measurement (in the air) is about two meters. Thus the pressure difference is $p = 2 \cdot 1.3 \cdot 9.8 \text{ Pa} = 25.5 \text{ Pa}$. This is usually in agreement with the measurements.

The density of water is greater that the density of air by three orders, so it is practical to calculate the change in pressure per 1 cm of depth: $p = 0.01 \cdot 1000 \cdot 9.8 \text{ Pa} = 98 \text{ Pa}$ .With each centimetre of depth the pressure increases by about 100 Pa. Therefore, the barometer can be used as a depth gauge; it works very nicely. It is good to notice that when we use the barometer as an altimeter (in the air), the linear relationship stated above only works approximately and for small height differences. In reality (air transport, etc.) it is necessary to include weather conditions (temperature, humidity, high-pressure areas etc.) and also the compressibility of air, i.e. the fact that with increasing altitude the density of air decreases.