Water Depth and Pressure

Theory

Just as we feel the weight of the air above us as "atmospheric pressure," when we venture underwater, we feel pressure from the weight of the water above us. If you have ever swum to the bottom of a deep pool, you may have felt discomfort in your ears. This is due to the increased pressure at that depth pushing on your eardrums.

In this experiment we will examine the relationship between pressure and water depth by measuring the pressure inside an open tube as it is placed at different depths. As the tube is lowered in the water, the water pressure at the open end of the tube is greater than the air pressure inside the tube. Thus, the water at the bottom of the tube presses up on the air inside the tube. This pressure causes the air in the tube to compress a small amount, which increases the air pressure inside the tube. The air will compress until equilibrium is reached between the water pressure at the bottom of the tube, and the air pressure inside the tube. Thus, by measuring the pressure of the air inside the tube, we are also measuring the water pressure at the open end of the tube.

Experiment

Use a Saltire Scientific barometer to investigate the relationship between water pressure and water depth

Materials

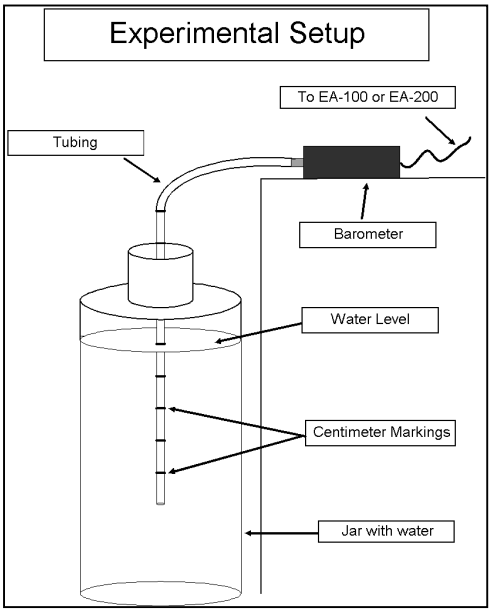
Casio Data Analyzer (EA-100 or EA-200)
Suitable Casio calculator
SB-62 Link cable
Saltire Scientific Barometer

Large container

Tubing with connector (provided)

Ruler

Permanent marker



Setup

To begin, fill your large container with water. Fill it almost to the top, but do not overfill. As you place your tubing in the water, the water level will increase. Try to take this in to account to avoid spills. The taller the container is, the more data points you will be able to take. At the least, you will want a large jar that is around 10cm deep or so. The barometer will reach its maximum pressure at around 30 cm of water. If you would like to measure deeper than this, you may wish to try this experiment with the Gas Pressure Sensor, as it can read much higher pressures (but is less sensitive to small pressure changes).

Connect one end of the tube to the barometer. *Use the connector on the tubing that is shipped with the barometer.* Starting from one end of your tube, mark centimeters on your tubing using the ruler and permanent marker. The end you start at will be the end of the tube that goes underwater. These marks will help you measure how far underwater the end of the tube is.

Step by Step

1. Copy the data table below into your notebook.

2. Connect the Saltire Scientific barometer to the CH-1 port of your data analyzer. Connect your calculator to the data analyzer with the SB-62 link cable. Turn both units on.

3. On your calculator, run the program called WATER. It will guide you through the experiment.

4. When prompted by your program, turn your tube upside down and hold it just above the water surface (so that the open end is facing downward.) *Throughout the experiment, take care that the barometer remains safely dry.*

5. When prompted by the program, lower the tube into the water so the first mark is level with the water surface.

6. Measure the pressure at this depth with the aid of your calculator. Enter the depth in inches when prompted (in this case the depth is 1 inch.)

7. Continue to lower the tube further into the water until the next mark is level with the water surface. Measure the pressure at this depth

8. Repeat step 7 as many times as desired (until you have reached the bottom of the container of water, or have run out of centimeter marks.)

9. When finished, your calculator will draw a graph of pressure versus water depth. Trace the graph, and record the data points in your data table.

10. Remove the tubing from the water, disconnect the tube from the sensor, and discard any remaining water.

Data Table

Water Depth (inches)	Pressure (kPa)

Sample Data

Water Depth (inches)	Pressure (kPa)
0	101.57
2	101.73
4	101.89
6	102.05
8	102.24
10	102.44
12	102.60

Discussion

1. **Using your graph, describe the relationship between water pressure and depth below the surface.**

2. **Would you expect this relationship to be linear? Why or why not? Does this graph support your prediction?**

3. **Use your calculator to run a linear regression on your data, and record the equation in your notebook. Is the line a good fit for the data?**

4. **Using your equation from question 3, at what depth (in centimeters) will the pressure underwater be twice that above water?**

5. **Suppose you had a balloon filled with 100mL of helium on land. How much volume would the gas take up if you brought the balloon 10m underwater? (Remember, Boyle's Law states that** $Pressure \times Volume = Constant$.**)**

6. **Besides the weight of the water above the tube, what else is contributing to the pressure felt at a certain depth? (Hint: why is the pressure under water always greater than 1 atmosphere?)**

Water Depth and Pressure – For the Teacher

GENERAL COMMENTS

This is a very simple experiment that is appropriate for all grade levels. As stated in the experiment, one must take care not to keep the barometer dry, to avoid any accidents. It may be useful to secure the end of your tube to a rigid object (like a ruler, or dowel.) This will ensure that the tube does not bend while in the water, and will allow for more accurate depth measurements.

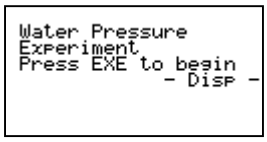
DISCUSSION POINTS

It should be noted that because the water pressure difference in a couple of inches of water is so slight, the data points may not all lie exactly on a line. However, a linear relationship should be evident. Less advanced classes can appreciate this relationship on a qualitative basis. More advanced classes can try to come up with a theoretical formula for the pressure as a function of water depth. Such a formula would have to take into account the atmospheric pressure above the water, and the density of water ($1 g/cm^3$), and the acceleration due to gravity ($9.81 m/sec^2$). Students could then compute the force due to a column of water with height h, and base area A from Newton's 2nd Law. Then, using the fact that Pressure = Force/Area, they can come up with the equation $P = \rho gd$. (Where P = pressure, ρ = the density of water, g = acceleration due to gravity, and d = the depth.) Students should then compare their theoretical function with their data. Alternatively, they can use their data to try to calculate the density of water (assuming the acceleration due to gravity is known). *Make sure you are consistent with units: in standard SI units, pressure is measured in Pascals, density in kg/m^3, and depth in meters.*

A good discussion of this material could begin with examining the consequences of an increased pressure at a low depth. Would organisms need to come equipped with special features to withstand this pressure? Why must submarines be designed with very strong walls?

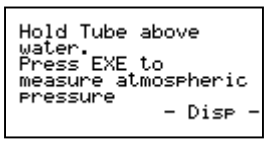
Water Pressure – Calculator Program Explanation

When you begin execution of the program called WATER, you will see an introductory screen that reminds you this is the water pressure experiment. Press EXE to begin the experiment

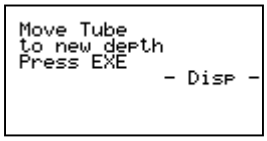


The next screen asks you to plug the barometer into the CH-1 port of the data analyzer if you have not done so already.

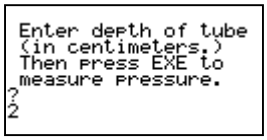
Your first measurement will be a measurement of atmospheric pressure. Hold the tube above the water, and press EXE to take this first measurement.



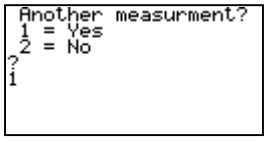
You are now ready to move the tube to different depths, and measure the pressure there. First, move the tube to your desired depth, and then press EXE.



Once you have positioned the tube correctly, you must enter the depth of the tube (in cm) on the screen at the right. Enter the depth, and then press EXE. Immediately after you press EXE, the pressure at the current depth will be measured.



You will be asked if you would like to take another measurement. You can take as many measurements at different depths as you like. Each time you select "Yes", you will be taken up to the 4th screen on this page. When you are finished with all your measurements, select "No"



When you have taken all your measurements, your calculator will display a graph of your data. You can trace the graph if you wish by pressing F1. Press ESC to exit the trace mode, and press EXE to finish the program execution.