Pool Plunge:
Linear Relationship between Depth and Pressure

If you dive to the bottom of a swimming pool you will feel an increasing pressure on your eardrums as you descend. The deeper you dive, the more water there is above you to push down on your body and your eardrums, so the more pressure you experience. There is a simple mathematical relationship between your depth in the pool and the pressure you feel.

In this activity you will lower a section of tubing into a water-filled pipe and collect pressure readings at different depths with the use of a Gas Pressure Sensor. You will then find a model for your data and use this model to understand the relationship between depth and pressure.
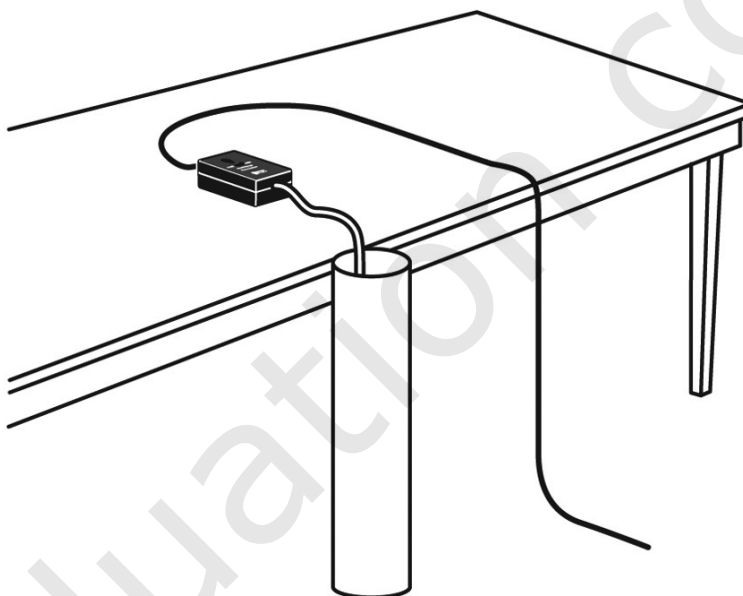

Figure 1

OBJECTIVES

- Record pressure versus depth data for water.
- Model pressure versus depth data with a linear relationship.
- Interpret the slope and intercept of the linear model.

MATERIALS

TI-Nspire handheld **or**
   computer and TI-Nspire software
data-collection interface
Vernier Gas Pressure Sensor w/ luer lock
1.2 m section clear tubing or pipe
1.5 m clear plastic aquarium tubing

cap to close one end of the tubing
weight heavy enough to pull the
   tubing to the bottom of the pipe
paperclip
meter stick
water

PROCEDURE

1. Make a small hole in one end of the plastic aquarium tubing. Attach a paperclip to the tubing through the hole. This clip will be used as a hanger for the sinker weight. At the other end, insert the luer lock.

2. Attach the sinker weight to the paper clip. Attach the other end of the plastic tubing to the white stem on the Pressure Sensor with a gentle half-turn of the luer lock.

3. With the clear pipe oriented vertically, cap down, secure the pipe safely to a stationary object. Fill the pipe with water, leaving a few centimeters of space at the top unfilled to allow for the tubing volume.

4. Connect the Gas Pressure Sensor to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.

5. Set up DataQuest for data collection.

   a. Choose New Experiment from the 🕱 Experiment menu.
   b. Choose Collection Mode ► Events with Entry from the 🕱 Experiment menu.
   c. Enter **Depth** as the Name and **m** as the Units. Select OK.

6. You are now ready to collect pressure and depth data.

   a. Start data collection (▣).
   b. With the weighted end of the tubing out of the water, wait until the pressure value stabilizes, click the Keep button (▣).
   c. Enter **0** as the depth. Select OK to store this data pair.
   d. Hold the meter stick so that the zero mark is even with the top of the water in the clear pipe, with the scale increasing downward. Lower the weighted end of the tubing into the pipe until the air-water line in the tubing is 10 cm below the water surface in the clear pipe. Adjust the meter stick and tube as needed so that there is a 10 cm air column in the tubing below the water surface (see Figure 2). Hold the tube in this position until the pressure value displayed on the screen stabilizes.

0 cm (0.1 m) mark is lined up with water level.

Measurements made at the air-water line, not the end of the tubing.

   e. Click the Keep button (▣) and enter **0.1**, or the depth in meters. Select OK.

Figure 2

   f. To collect another data point, lower the tube so that the air-water interface is 20 cm deep. When the pressure reading stabilizes, click the Keep button (▣), enter 0.2 as the depth in meters, and select OK.
   g. Continue in 10 cm increments with 0.7 m as the last point.
   h. Stop data collection (▣) when you have finished collecting data.

7. The pressure versus depth plot should be nearly linear. If you are not satisfied with the data, repeat Step 6. If you are satisfied with the data, make a rough sketch of the pressure versus depth data.
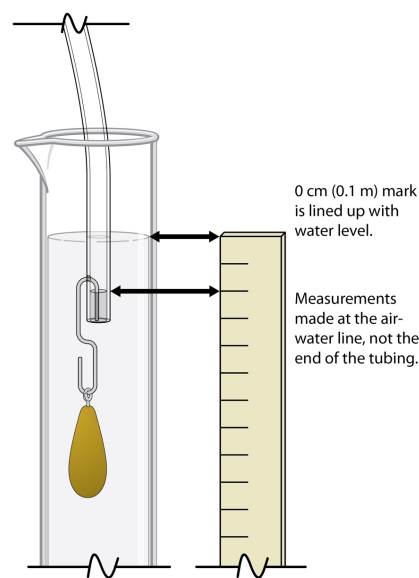
ANALYSIS

1. Click the Table View tab (▦). Choose any two points (x_1, y_1) and $(x_2, y_2,)$ along the data plot and record them in the data table below. Round the pressure values to the nearest kPa.

x:Depth (m)	y:Pressure (kPa)

Answer Analysis Questions 1–3.

2. Create a Graphs page so you can model the graph with a linear function.
   a. Insert a Graphs page.
   b. Insert the Sensor Console in order to input the graph from DataQuest. Verify that your data appears and then close the Sensor Console.
   c. Choose Zoom – Data from the ⊹ Window/Zoom menu to view all of your data.
   d. Chose Function from the ⊹ Graph Type menu.
   e. Enter your model equation into the Entry Line replacing *m* and *b* with the values you determined earlier.

$$f1(x) = mx + b$$

3. Experiment with your movable line to find the best value for *m* and *b* by grasping the line to translate and rotate it.

   Answer Analysis Question 4.

4. Instead of using a model from only two points, you can have DataQuest perform a linear regression on all the data points.

   a. Return to your DataQuest page.
   b. Choose Curve Fit ► Linear from the ⊠ Analyze menu.
   c. Use the parameters *m* and *b* to answer Analysis Questions 5 and 6.
   d. (optional) Print your graph.

ANALYSIS QUESTIONS

1. Use the points in the data table to compute the slope, *m*, of the pressure versus depth line and record it.

$$m = \frac{y_2 - y_1}{x_2 - x_1} =$$

2. You can model the data with a linear equation of the form $y = mx + b,$ where *b* represents the *y*-intercept (that is, the zero-depth pressure reading). Move to $x = 0$ and record the *y*-intercept value.

3. Use the values of *m* and *b* you determined to write a linear equation that models your data, and record it.

4. Is your line a good fit for the data? Does the line pass directly through any points?

5. Use the parameters *m* and *b* that appear on your screen to write the equation fit by DataQuest.

6. Is the line suggested by the regression consistent with your results you calculated above? Why might they be different?

APPLICATIONS

Use the regression equation developed in this activity to solve the following problems.

1. Recall that the first pressure reading in this activity was out of the water. This pressure is known to be 1 atmosphere (atm). How many kPa (kilo Pascals) are equal to 1 atm?

2. Your cousin Susie is always bragging about her exploits. When you tell her that you touched the bottom of your 4 m deep pool she quickly responds that her pool is two-and-a-half times that deep, and she always touches the bottom. Use your model to find the pressure at the bottom of Susie's pool.

3. Beginning divers are advised not to swim in deep waters where the pressure exceeds about 275 kPa. Use your model to determine how deep a novice diver can safely swim.

4. The Mariana Trench contains some of the deepest waters ever measured on Earth. One location, called the Challenger Deep, was found to be 11,033 m. Use your model to predict the pressure at this depth.

    At this depth, what is the pressure in atmospheres?

5. The wreck of the Titanic rests on the floor of the Atlantic Ocean nearly 4 km beneath the surface of the water. What is the pressure on the remains of the hull at this depth? **Hint:** 1 km is 1000 m.

Vernier Lab Safety Instructions Disclaimer

This copy does not include:

- **Safety information**
- **Essential instructor background information**
- **Directions for preparing solutions**
- **Important tips for successfully doing these labs**

The complete *Real-World Math with Vernier* lab manual includes 32 activities and essential teacher information. The full lab book is available for purchase at:
http://www.vernier.com/products/books/rwv/