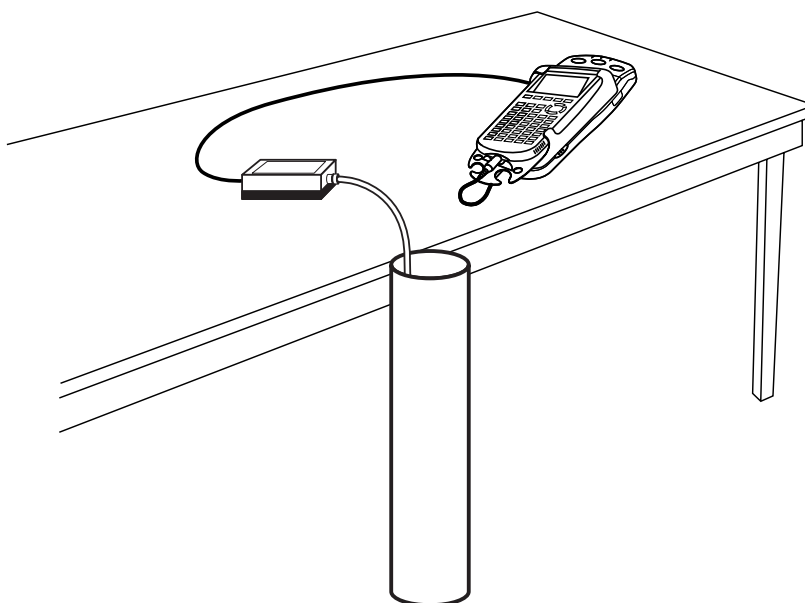


Pool Plunge: Linear Relationship between Depth and Pressure

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.



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-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
Vernier Gas Pressure Sensor
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.
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.
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 cm at the top unfilled to allow for the tubing volume.
4. Turn on the calculator. Connect the Pressure Sensor, data-collection interface, and calculator.
5. Set up EasyData for data collection.
 - a. Start the EasyData application, if it is not already running.
 - b. Select **(File)** from the Main screen, and then select **New** to reset the application.
 - c. Select **(Setup)** from the Main screen, and then select **Events with Entry**.
6. You are now ready to collect pressure and depth data.
 - a. Select **(Start)** to begin data collection.
 - b. With the weighted end of the tubing out of the water, wait until the pressure value stabilizes, then select **(Keep)**.
 - c. Enter **0** on the calculator for 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. Hold the tube in this position until the pressure value displayed on the calculator screen stabilizes.
 - e. Select **(Keep)** and enter **0.1**, or the depth in meters. Select **(OK)** to store this data pair.
 - f. To collect another data point, lower the tube so that the air-water interface is 20 cm deep. When the pressure reading stabilizes, select **(Keep)**, 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. Select **(Stop)** when you have finished collecting data. A graph will be displayed.
7. The pressure versus depth plot should be nearly linear. If you are not satisfied with the data, select **(Main)** to return to the Main screen and repeat Step 6.
8. If you are satisfied with the data, make a rough sketch of the pressure versus depth data. Select **(Main)** to return to the Main screen. Exit EasyData by selecting **(Quit)** from the Main screen and then selecting **(OK)**.

ANALYSIS

1. Before you can work with the data on the calculator, you need to redisplay the graph outside EasyData.
 - a. Press 2nd [STAT PLOT].
 - b. Press ENTER to select Plot1 and press ENTER again to select On.
 - c. Press ZOOM .
 - d. Press 2nd until ZoomStat is highlighted; press ENTER to display a graph with the x and y ranges set to fill the screen with data.
 - e. Press TRACE to determine the coordinates of a point on the graph using the cursor keys.
2. Use the cursor keys to move along the data points. Choose any two points (x_1, y_1) and (x_2, y_2) along the data plot and round the pressure values to the nearest kPa. Record these data points in the Data Table on the *Data Collection and Analysis* sheet.

⇒ Answer Questions 1–3 on the *Data Collection and Analysis* sheet.

3. Next, plot the line whose equation you just determined in Question 3. You can plot the line on the same graph as your data.
 - a. Press Y= .
 - b. Press CLEAR to remove any existing equation.
 - c. Enter the equation for the line you determined in the Y_1 field. For example, if your expression is $y = 4x + 3$, enter $4*x+3$.
 - d. Press 2nd until the icon to the left of Y_1 is blinking. Press ENTER until a bold diagonal line is shown in order to display your model with a thick line.
 - e. Press GRAPH to see your data with the model graph superimposed.

⇒ Answer Question 4 on the *Data Collection and Analysis* sheet.

4. You can use the calculator to do a linear least-squares fit to the data. Instead of using only two points to determine the slope, the calculator can be used to automatically determine the slope and intercept for the line that bests fits the data.
 - a. Press STAT and use the cursor keys to highlight CALC.
 - b. Press the number adjacent to LinReg(ax+b) to copy the command to the home screen.
 - c. Press 2nd [L1] 2nd [L2] to enter the lists containing the data.
 - d. Press VAR and use the cursor keys to highlight Y-VARS.
 - e. Select Function by pressing ENTER .
 - f. Press ENTER to copy Y_1 to the expression.
On the home screen, you will now see the entry LinReg(ax+b) L1, L2, Y1. This command will perform a linear regression with L1 as the x -values and L2 as the y -values. The resulting regression line will be stored in equation variable Y_1 .
 - g. Press ENTER to perform the linear regression.

⇒ Use the parameters a and b that appear on the calculator screen to write the equation fit by the calculator and record it in Question 5 on the *Data Collection and Analysis* sheet.

 - h. Press GRAPH to see the graph.

⇒ Answer Question 6 on the *Data Collection and Analysis* sheet.

DATA COLLECTION AND ANALYSIS

Name _____

Date _____

DATA TABLE

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

QUESTIONS

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

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

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). Use the cursor keys to move the cursor to $x = 0$ and record the y -intercept value here.

$$b = \underline{\hspace{2cm}}$$

3. Use the values of m and b you determined to write a linear equation that models your data, and record it here.
4. Is your line a good fit for the data? Does the line pass directly through any points?
5. Use the parameters a and b that appear on your calculator screen to write the equation fit by the calculator. Record it here.
6. Is the line suggested by the regression consistent with your results from Step 4? 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?

_____ kPa

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 and record your answer in the space below.

_____ kPa

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

_____ m

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, and record your answer in the space below.

_____ kPa

At this depth, what is the pressure in atmospheres?

_____ atm

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.

_____ atm