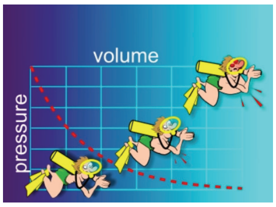
INVESTIGATION WATER DEPTH PRESSURE



Cartoon from http://resources.yesican-science.ca/Bolyes_law/

I am an active scuba diver. When I swim underwater you can feel a slight pressure on my ears. This is due to the weight of the water overhead. The deeper I go the more water is overhead, and so the pressure increases. We are told that at a depth of 33 feet the pressure is twice. Here is a table of pressure and depth.

PE The student's scuba diving interest directs the study of this investigation. This demonstrates some personal significance, interest and curiosity. The actual method and design of the experiment is given to the student by the pressure sensor data sheet.

EX The student explains in a basic way the phenomenon under study and places it in a real world context. This aspect is nicely done.

Total Pressure at Standard Depths*
Depth / Atmospheric Pressure + Water Pressure / Total Pressure
0 feet / 1 ATA + 0 ATA / 1 ATA
15 feet / 1 ATA + 0.45 ATA / 1 .45 ATA
33 feet / 1 ATA + 1 ATA / 2 ATA
40 feet / 1 ATA + 1.21 ATA / 2.2 ATA
66 feet / 1 ATA + 2 ATA / 3 ATA
99 feet / 1 ATA + 3 ATA / 4 ATA

http://scuba.about.com/od/scuba101/a/Under-Pressure.htm

This water pressure can be dangerous for humans but some deep-sea animals have no trouble with high pressure. Whales, for example, can withstand dramatic pressure changes because their bodies are more flexible. Their ribs are bound by loose, bendable cartilage. This allows the rib cage to collapse at pressures that would snake human bones. A whale's lung also collapses safely under pressure. Whales can go as deep as 2.1 km under water. More amazing details can be found in an article "Pressure increase with ocean depth" on the Internet web site from the National Oceanic and Atmospheric Administration.

My teacher showed me an equation that tells me how the pressure is a function of water depth, gravity and water density. Here is the equation: $P = h\rho g$

EX This is indeed the relevant equation, and the method is now straightforward. Technically, the pressure at a given depth is one atmospheric pressure plus the value determined by the equation.

For the density of water and the value of gravity, we see that pressure is directly proportional to depth. For my physics exploration I will investigate this law of physics in the physics lab, using a pressure gauge and a cylinder of water. My purpose is to prove or disprove the theory.

EX and **C** The student will confirm the relevance of the equation within the limits of their study. It is the nature of science that we never really prove a theory. The language of the student misleads the reader.

1

MY SCIENTIFIC METHOD

My physics investigation will measure this equation, and hopefully prove it is true. I will use a computer, a pressure sensor, a measuring cylinder filled with water, and a rubber tube inserted into the water at various depths. I will measure the end of the rubber tube from the water surface. I will keep all my measurements in SI units. I will follow the 100 mL marks on the cylinder but measure the depth with a ruler.

EX Although not mentioned, the teacher knows that the method is a direct copy from Vernier's pressure sensor data sheet. This is not plagiarism, but reference should be given.

Safety issues were to be careful not to spill or set up the equipment in a dangerous way, and I paid attention to environmental issues, such as not spilling the water so as to waste it.

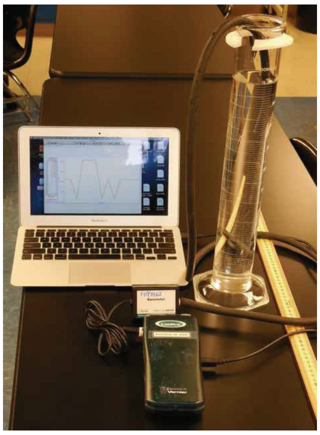
EX Basic safety in the lab is recognized. The environmental issue is not too relevant as the student would have tossed out the water anyway at the end of the investigation.

UNCERTAINTIES

The Vernier pressure sensor is given an uncertainty of only 0.1%, which is too small to think about. The uncertainty in this experiment comes from the depth measurement. First, I have to look through glass, and second, the rubber tube curves slightly, and third, the end opening has a width. Overall, I estimate and uncertainty of depth as 5 mm or ±0.005 m for my graphing works.

A Uncertainties are addressed and estimated appropriately.

PICTURE AND DATA



My Experiment

	Data Set	
	Depth (m)	Pressure (kPa)
1	0.000	82.695
2	0.032	82.895
3	0.065	83.295
4	0.101	83.495
5	0.134	83.895
6	0.167	84.195
7	0.203	84.495
8	0.240	84.795
9	0.275	85.095
10	0.313	85.395

My Raw Data.

2

PHYSICS THEORY

The theory is that the water pressure increases the pressure going to the sensor, and this is recorded on the computer. Instead of using a time base, I selected manual data entry, and entered the water depth each time for a given measure of pressure.

In theory, the gradient of the graph should be 9.81 kPa m^{-1}, where gravity is 9.81 m s^{-2} where the density of water is 1000 kg m^{-3}. This theory comes from the equation:

EX and **A** This is relevant and interesting. Appreciating the gradient is one sign of understanding demonstrated by the student.

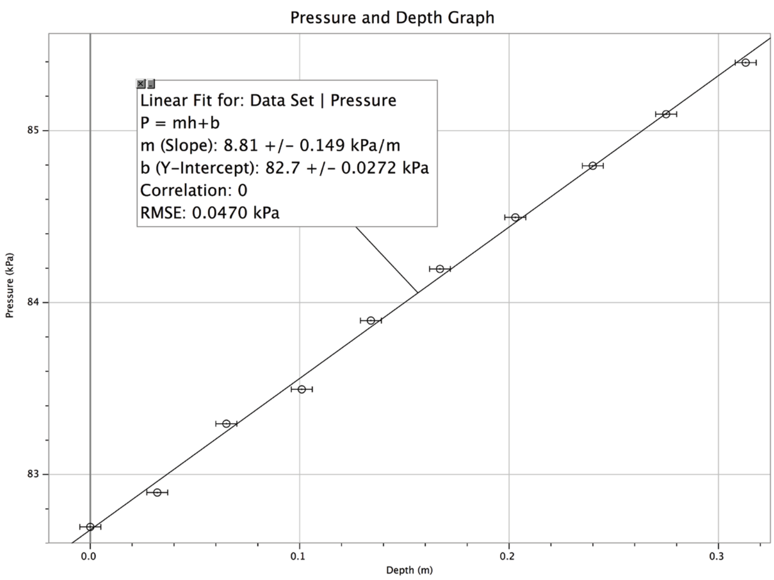
EV The student needs to be more thoughtful in selecting the data for the theoretical value of the gradient, although this approach is most relevant.

$$P = h\rho g \rightarrow \frac{P}{h} = \rho g$$

$$\text{slope of graph}\left(\frac{\Delta P}{\Delta h}\right) = \rho g = \left(1000\,\text{kg m}^{-3}\right)\left(9.81\,\text{m s}^{-2}\right) = 9810$$

EXPERIMENTAL RESULTS GRAPH

A A most appropriate graph, with error bars and a gradient. The data looks good here. Note that the pressure axis does not start at zero and later on the student misread the graphed results.



3

CONCLUSION and EVALUATION

In practice, my experiment yields a slope of (8810) or 8.81 kPa m^{-1}.

This gives me an experimental error of $\frac{9.81-8.81}{9.81}\times 100 = 10.2\%$

Although 10% is noticeable it is very good for my experiment, as the graph itself is proportional with a zero-zero origin. Almost all the error bars (almost) touch the best straight-line. The computer tells me the graph correlation is 0.999 and that is amazingly good, so my data are precise and accurate.

My conclusion is obvious, namely: that the pressure increases in a proportional way with the depth. And I know for to 10% uncertainty. I was careful to keep SI units throughout the experiment and I appreciated uncertainties.

IMPROVEMENTS AND EXTENSIONS

(1) With more time I would make more measurements. Perhaps I could use a rain barrow with much greater depth.

(2) I should have attached the rubber tube to the zero end of meter stick, immerse the stick with the tube fixed into the water keeping it vertical, and then read the depth from the ruler at the water surface. This would improve the precision by several millimeters I am sure.

(3) I found a web site that calculated the theory of pressure with water depth. I could use this data with my measurement and obtain higher precision, to five decimal places.

A The gradient and its uncertainty are correctly expressed.

EV No, the graph does not go through a zero-zero origin. The pressure axis has an intercept of 82.7 kPa.

EV Well, it is not so obvious to the student who 'sees' a proportional graph line. Also, there is a serious flaw in the appreciation of the data. There is air in the end of the rubber tube that changes the effective depth, while the student measured the depth as the end of the rubber tube. This is a major error in the method and hence is reflected in any conclusion.

EV The improvements are reasonable, and the student can be seen to be thinking here. Using a deeper water source is not an extension but rather an improvement. There are no extensions mentioned.

REFERENCES

The value of gravity, the density of water and the pressure equations all come form our textbook, "Physics: Principles with Applications" fifth edition by Douglas Giancoli, Prentice Hall Publishers.

And more details about the equations of water depth and simple experiments can be found online at: http://library.thinkquest.org/26586/Pressureunderwater.htm

And even more details can be found at: http://en.wikipedia.org/wiki/Underwater

Web site for calculating water depth pressure:
http://www.calctool.org/CALC/other/games/depth_press

For an article on water depth and whales see:
http://oceanservice.noaa.gov/facts/pressure.html