Hydrostatics: Pressure vs Depth

Name:

PES 115 Report

Lab Section:

Objective

The purpose of this lab was to establish the fundamental theory for the relationship between pressure and depth in a liquid.

This day has been a long time coming, but it is finally time for you to leave the nest and try writing the reports on you own!

Data and Calculations

~~Part A:~~

We used a pressure sensor and a vessel of water to measure the relative pressure versus the depth.

When performing this experiment we had to be very careful to establish the coordinate frame of reference. In a standard coordinate frame, depth is measured from the surface of the water to the point of measurement – hence, it is pointing *down*, and thus should be negative when measured.

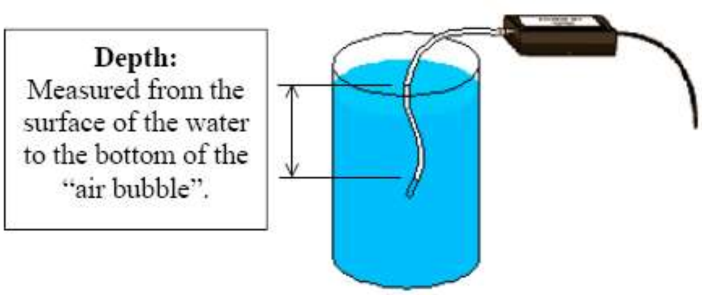

Figure 1: Experimental Setup of the Lab using the Pressure Sensor Explicitly Indicating the Coordinate Frame

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We made several measurements (in increments of 5 cm) of the pressure versus the depth and obtained the following results from Logger Pro:

Depth (m)	Pressure (kPa)
0.00	81.773
-0.05	82.2501
-0.10	82.7363
-0.15	83.2474
-0.20	83.7222
-0.25	84.2107
-0.30	84.7105
-0.35	85.1921
-0.40	85.6874

After changing the kPa to Pa, the data looked like the following:

Depth (m)	Pressure (Pa)
0.00	81773.0
-0.05	82250.1
-0.10	82736.3
-0.15	83247.4
-0.20	83722.2
-0.25	842107
-0.30	84710.5
-0.35	85192.1
-0.40	85687.4

This seems to be somewhat systematically inaccurate – since the Barometric Atmospheric Pressure in Colorado Springs during the lab was 100,082 Pa – which compared to 81, 773.0 is not exact (which is precisely the value we measured at a depth of 0 meters with the pressure sensor). The saving grace is: The slope is not a function of the initial pressure.

Next, I plotted the pressure versus depth and got a best fit line.

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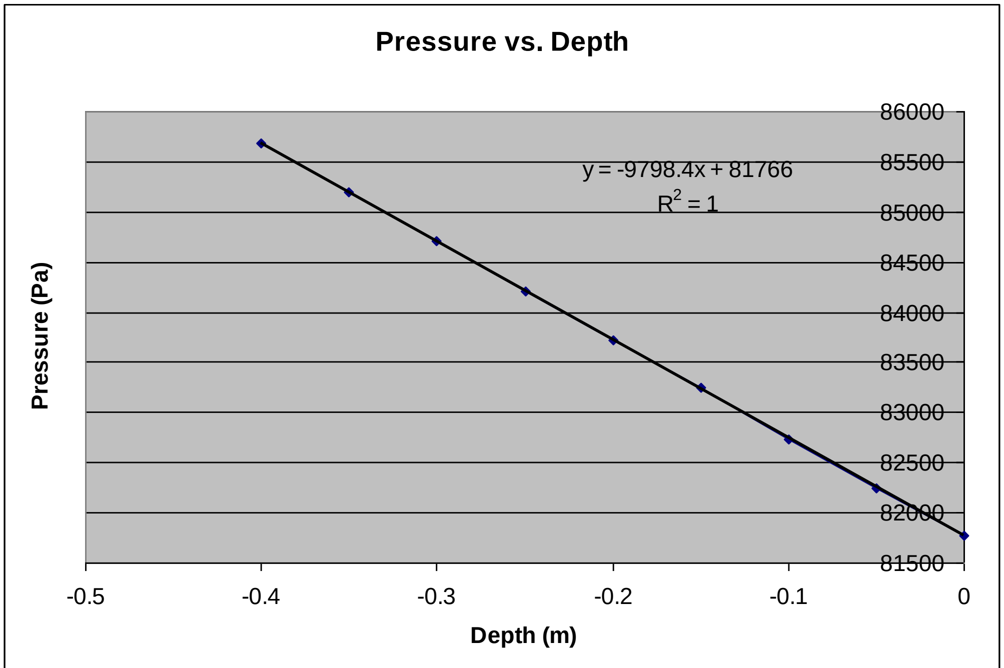

Figure 2: Graph of Experimentally Collected Data

Using the trendline feature in Excel, we got the following best fit line:

$$y = \left(-9798.4 \frac{kg}{m^2 s^2}\right)x + (81766\, Pa)$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 1.0. This means that the "linear nature" of the data is *extremely* good.

If we compare the equation for pressure as a function of depth with the found trendline, we can easily see by evaluation that the following constants correlate directly:

$$P(h) = \rho g h + P_0$$

$$y = \left(-9798.4 \frac{kg}{m^2 s^2}\right)x + (81766\, Pa)$$

Thus:

ρg [kg/m^{2}s^2]	P_o [Pa]
-9798.4	81,766.0

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Additional Questions

- Compare the value you obtained for "P_o" to the intercept of your graph with a percent error calculation. What is the physical significance of the intercept of the graph?

$$\%\ difference = \frac{\left|P_{o\,Theory}\right| - \left|P_{o\,Measured}\right|}{\left|P_{o\,Theory}\right|} x100\% = \frac{(100082.0\ Pa) - (81766.0\ Pa)}{(100082.0\ Pa)} x100\%$$

$$\boxed{\%\ difference = 18.3\%}$$

The y-intercept of the Pressure versus Height graph is the measured atmospheric pressure.

- The slope of your graph should be ρg where ρ = 1000 kg/m^3 (density of water) and g = -9.81 m/s^2 (acceleration due to Earth's gravity). Compare these two values with a percent error calculation. (Watch your units!)

$$\%\ difference = \frac{\left|\rho g_{Theory}\right| - \left|\rho g_{Measured}\right|}{\left|\rho g_{Theory}\right|} x100\% = \frac{\left(-9810.0 \frac{kg}{m^2 s^2}\right) - \left(-9798.4 \frac{kg}{m^2 s^2}\right)}{\left(-9810.0 \frac{kg}{m^2 s^2}\right)} x100\%$$

$$\boxed{\%\ difference = 0.1182\%}$$

Of course, we know that the acceleration due to gravity at our altitude is not precisely the value measured at sea-level. So, this seems reasonable.

- What would happen to the pressure of the water at any depth if atmospheric pressure (i.e. P_o) increased suddenly? In your explanation, explain how the graph you printed in Step 11 would change.

If the atmospheric pressure increased/decreased the slope of the line would not change, but would be shifted up (for and increase) or down (for a decrease). This would be representative of a systematic error (which according to the barometric reading – is precisely the issue we have).

- What would happen to the graph you printed if you used a more dense fluid, such as oil, instead of water in your measurements?

If we had used a different fluid, we would have had a different slope for the best fit line.

- As you look around the room you will notice that other lab groups have different shaped water vessels. Reexamine the equation on pressure vs. depth and determine if the volume or just the depth determines the pressure.

This is a trick question. Pressure is a function of the depth below the surface (as shown by the data) and not a function of the volume of the vessel in which the water is stored. However,

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Pressure is a function of the volume *above* the object being measured. This however is represented by the density in our equation.

- ~~question 1~~

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Conclusion

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Parallax
- Concave and convex bending of light
- Ruler measurement
- Curvature of the tube
- Pressure sensor calibration
- Clarity of instructions
- No barometer available to measure atmospheric pressure in the room
- Other …

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A few of the potential errors listed above may be applicable to YOUR experiment.