# Lab 7 manual: Pressure in Liquids

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For PHYS 1111L and PHYS 2212L

(Lab outcomes: Instrument calibration correction, use of computer-based sensors and data acquisition using Pasco Capstone software [1].)

## Abstract

This experiment allows to measure the unknown liquid density using the pressure sensor. Comparison with a known liquid is added to factor out the calibration offsets. The result is compared with accepted value. The fit and method are used to obtain the density value, the error on the density is obtained from the linear regression. Other software fitter use is allowed.

## Introduction

The dependence of pressure in liquids has been studied by Pascal and others, perhaps some historic background might be relevant. There are many devices based on hydraulics that are being used today such as car lifts, presses, some mall elevators, and others. The blood pressure in a person is also due to the person’s height in part. So, the study of the pressure dependence on heigh in the liquid is of practical and medical interest.

The main motivation for this lab is the ability to use the sensor with the calibration that has been misaligned in the unknown way. Other new skills will include the use of the computer-based data acquisition and use of the Capstone software. DO NOT SAVE THE OPEN FILE!

## Experimental Setup

An experimental setup schematic is shown in Figure 1 and includes the pressure sensor (Figure 1a), graduated cylinder with liquid (Figure 1b) and a ruler (Figure 1c). The sensor is connected to a computer for the readout.

a)

Pressure sensor

Ruler

b)

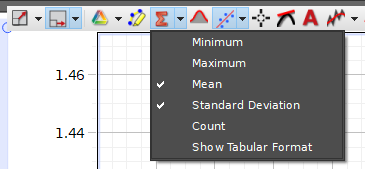
c)

Figure : The experimental setup schematic. A pressure sensor (a) is used to measure the pressure at the known heights in the filled with liquid cylinder (b) with a ruler (c).

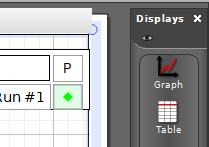
### Procedure

PART I

For part 1, we try to estimate the statistical and systematic errors of the measurement of pressure using the PASCO pressure sensor. To do that, fill the cylinder with water and submerge the measurement probe (the open end of the rubber hose) to some level about ¾ of the total height. Measure this height using the ruler. Click the record button and collect data for several seconds. During this collection, hold the probe with your fingers and give it some slight vibration or back and forth motion (do not move it up and down!). You can slightly rock the cylinder instead.



Now, open the graph display for the pressure in Pasco Capstone program (pointed by green arrow). After that, click on the downwards arrow next to symbol and make sure that Mean and Standard Deviation are checked exactly as shown. After that, make sure that tool is active, that is, its highlighted by the light blue frame.



Next, click on the select tool (yellow pencil with blue dots, pointed by orange arrow). Highlight the part of the data that shows reasonable deviations from the average value. If you moved the probe a lot and deviations seem unreasonable, erase the run, and try again. If all seems ok, record the mean and the standard deviation values as shown in Figure 2. Sometimes you need to increase the precision to see more decimal points for the values displayed. (Hint – you want to zoom in to highlight the data. There are few ways to do that, you can start with the zoom tool pointed by blue arrow). This stdev is the statistical error of measurement.

Chart

Description automatically generated

Figure : The highlighted part of data and the Mean and Standard deviation values.

Remove the probe and insert it back to the same height as measured by ruler at least 4 more times. For each try, record the data for a few seconds and write down the new average. Find the stdev of these five values (with one recorded together beforehand) in Excel or similar tool – it can be used as the systematic error for the pressure. It includes all the uncertainties of how well each point position can be measured and reproduced.

We will use these error values for all measurements. At this time, you might want to combine the statistical and systematic errors into a single one – add in quadrature!

What is your error for the height measurement? It is one or two measurements?

*Now for the actual measurement:*

Start by inserting the probe all the way to the bottom of the cylinder (make sure the opening of the hose is not covered). Start recording, stop, write down the average as pressure, and the height as measured by the ruler. Repeat this 4-5 times, with each step changing the height by approximately 3-5 cm or so. You should have pressure vs. heigh data set for water.

(**Question**: you can choose to measure the height of the liquid column from the top, or you can choose to measure the height from the bottom of the cylinder or even from the table. Why doesn’t that matter? Regardless of your choice, please answer this question after completing the analysis as the reason would be much more evident.)

Empty and dry the cylinder. Fill it with unknown liquid. Do the pressure measurements vs. height in the same way as for water. You should have pressure vs. heigh data set for unknown liquid (at least 5 data points should be present). Pour the unknown liquid back into the container, wash the cylinder and the data probe with water and let it dry. Tidy the workplace.

## Experimental Data

Organize the results of the measurements in tables such as Table 1. The error can be listed in a different column (this is more convenient if copied from Excel), or as value ± error unit. Don’t include every single measurement here, only relevant means, stdev etc. if you measured same values few times. All data values may be included in the Appendix if desired.

Table : Experimental data sample table.

|  |  |
| --- | --- |
| Pressure, Pa | Height, m |
|  |  |
|  |  |

Provide description about each entry or table as needed, don’t just leave the table without text in this section. Organize well so that data takes less space, but everything needed is included.

## Theory

The equation of pressure vs. height should be derived by PHYS2211L students, PHYS1111L will get extra points for doing this. The resultant equation is:

written using the density of the liquid , the acceleration of free fall g and the height of the liquid column h. Ideally, we could measure just one dataset of pressure and height and be able to get the liquid density. Why do we measure at least 5 points?

As we have a dataset of at least 5 points or more for each liquid, we can make a plot of and fit it for a more precise value of density. The slope would be the . However, the sensor that you used has lost its calibration in the unknown way. So, each group’s measurement will be different due to this shift in the sensor calibration. We should do something to remove this contribution.

## Analysis

We shall assume that the model for the sensor calibration loss is linear of the form:

where a and c are the unknown coefficients describing the loss of the calibration.

Parameter is the offset – that is, the baseline pressure that used to be set to 0 has drifted away. However, when do the plot of and fit it, we automatically take care of this coefficient since we are only interested in slope and not offset. This will be the coefficient in the linear fit (recall line equation: ) and will be discarded.

Its harder to deal with parameter . The slope from the fit will be in reality , and the best we can get from it is , and **not** the liquid density. So, was all the work for nothing?

Good news! What if we have two samples, a measurement of a known liquid such as water, and a measurement of the unknown liquid? From each fit we will get for water and the . If we take a ratio of the two, the coefficient will cancel! Thus, we use:

From equation 3 we can finally find the density of the unknown liquid.

Thus, plot the for both datasets. Include the error bars, find and the error of the slope using linear regression. Reminder: We are interested in the x variable value (not the intercept) and its error as shown in Figure 3. Here Excel calls slope , not as usual. And intercept is .

Table

Description automatically generated

Figure : The linear regression relevant values.

Now use the two slopes (with errors) and equation 3 to find the density of the known liquid. Density for water is . Propagate errors, can use simplified formulas for PHYS 1111L.

Last step. If you used the unknown liquid provided, you were probably told what the name of it (typically, its glycerin but something else might be used as well). Find the accepted value for that liquid and do the %discrepancy with your result. Comment on it within the errors.

However, if you used the isopropyl water mixture that is available as hand sanitizer, try to estimate what are the fractions of water and isopropyl in the mixture. For that, you can use the following simple model:

where is the value you just calculated from equation 3, and A and B are the fractions of each component in the mixture. As we have two variables to find and only one equation, we should come up with a second equation so that this system can be solved:

This condition states that both A and B should be 100% when added together. Propagate the error from your measured value to A and B (show all equations!). Does your answer make sense? What do you expect to get from your knowledge about hand sanitizers[[1]](#footnote-1)?

## Conclusion

Discuss the results. How was the density of the unknown liquid, did you get to the accepted value within errors? What about its composition if it was a mixture? Any other thoughts and comments?

# References

|  |  |
| --- | --- |
| [1] | *PASCO Scientific,* 10101 Foothills Boulevard, Roseville, California 95747 USA. |

1. If the hand sanitizer is used, the nominal concentration may not be known. If you were provided the specially prepared mixture, the A and B will be known. In this case, do the % discrepancy for both coefficients. [↑](#footnote-ref-1)