1291/2 Physics Lab Report Format

General Remarks:

Writing a lab report is the only way your TA will know what you have done during the lab and how well you have understood the process and the results. Part of your lab experience should be learning how to organize and present your work in a scientific way. There is no framework that can be used as a "one size fits all", therefore this sample lab report should only be used as an example.

Any lab report should have the following features:

- It should be concise but should also contain the necessary details and well-developed explanations.
- It should be organized. You should enable the reader to quickly find the information he or she may be interested in.
- It should contain all the relevant information and reasoning. You should enable the reader to validate your conclusion.

A possible way to achieve this is using the following framework:

- **Objective:** State what you want to achieve in this experiment. A formal way to do this is to state a question or hypothesis that you want to address. This should be the scientific goal of the experiment, not the educational goal (though you should understand that too). One or two well thought out sentences is all that you should need for this.
- **Method:** You should include a summary of the lab procedure *in your words*; do not merely copy what is in the manual. This section should demonstrate your understanding of exactly what you measured, how you measured it, and why this measurement helps you answer the question you posed in the objective section. You don't need to detail each step of math that you will do in the analysis, just what your general approach will be for getting your raw data to answer the question you are interested in. This section should not be more than about half a page.
- **Data:** In this section you should include the raw data you measured; generally, an estimate of the error should accompany all measured values as well as a brief note on how that error estimate was arrived at. Be sure to present your data in an organized manner (e.g. a data table) and to include units.
- **Data and Error Analysis:** In this section you will manipulate the data in order to help you address your question or hypothesis. Usually this entails performing calculations and/or creating graphs of the data. You cannot draw any final conclusions from your data until you think carefully about how well you can trust your data and what factors may have affected or biased it. Additionally, you must often propagate the error from your measurements through your calculations and graphs. It is generally easier to do the main calculation first, then calculate the uncertainty separately to come up with the final value.

- **Conclusion:** Finally, after all this work, go back and answer the question you stated in the beginning. Does your data allow you to support or reject your hypothesis, or is the data inconclusive? Also do you have anything you can compare your results with (e.g. a value in the literature, a second measurement, a measurement with a different method, other lab groups)? How well does it compare to such a value?

<u>Some tips on writing a good lab report:</u>

- The most important thing for getting a high score is to show that you understood the experiment and performed it carefully. This may sound straightforward or obvious, but it requires a little bit more thought than just following the lab manual blindly. If you get a result or an uncertainty that is ridiculous (or just really big/small), show that you have noticed and thought about it, not just copied a number from your calculator and moved on.
- In order to demonstrate your understanding, clear presentation is key. If one has to hunt around for your results or read through lots of meaningless statements in order to get to your conclusion, you will give the impression that you don't understand what the important and interesting parts are.
- Make sure that your words and actions are consistent. If you write about some great way to reduce uncertainty, but didn't do it, the grader will wonder why.
- Ideas that are backed up by tests (even if not explicitly asked for by the lab manual) are much more impressive than speculation.
- Make sure you understand uncertainty at the start of the semester because it isn't going anywhere.
- If you don't think you will be able to finish the lab in time, prioritize. You should leave yourself at least 45 minutes to do the analysis and write up the report, so plan ahead. It is frustrating to see a report with intricate uncertainty calculations, but that fails to actually reach a conclusion. Ask the TA if you need help deciding which parts are most important.
- If there are multiple parts to an experiment (as there usually are), it is best to write all the sections for one part together, then writing all the sections again for the other part. This allows the grader to follow what you did easier than if you have one big methods section, one big data section, one big analysis section, etc.
- You really only need to claim that there was a significant systematic error if your result doesn't match the expected value within your claimed uncertainty. If it does, you are saying that random errors are enough to explain the difference between the two. If not, make sure the systematic error you are proposing would affect your result in the right direction. For example, if the distance you measure is longer than expected, claiming that your meter stick is thermally expanded doesn't help your cause.

The following pages contain a sample lab report for an experiment where we observe how the water level in a 2-liter soda bottle changes as more and more water is added.

Lab Report – Soda Bottle Experiment

Name: Roary the Lion
Partner: Lionel Columbus

Objective:

Given that a soda bottle roughly resembles a cylinder, we expect a linear relationship between the height of the water and the amount of water filled in. That relationship will be tested and, if it holds, will be used to measure the circumference of the bottle.

Method:

We measure the height of the water after each time we pour in 250 mL. The volume is measured by filling the beaker to the 250 mL line, while the height is measured by holding a ruler up to the side of the bottle. We estimate that we were able to measure the volume with a precision of ±25mL and the water level with a precision of ±0.5cm, both due to the inherent limitation of trying to match the surface of water to a line on the measuring device by eye.

If we model the soda bottle as a cylinder, the height and volume of the water are related by

$$V = A \cdot h .$$

To test for the linear relationship, we will make a best line fit in a V-h diagram where the slope will equal the horizontal cross sectional area of the bottle. We can find the circumference using

$$A = \pi \cdot r^2 = \pi \cdot \left(\frac{C}{2\pi}\right)^2 = \frac{C^2}{4\pi} \rightarrow C = \sqrt{4\pi A} .$$

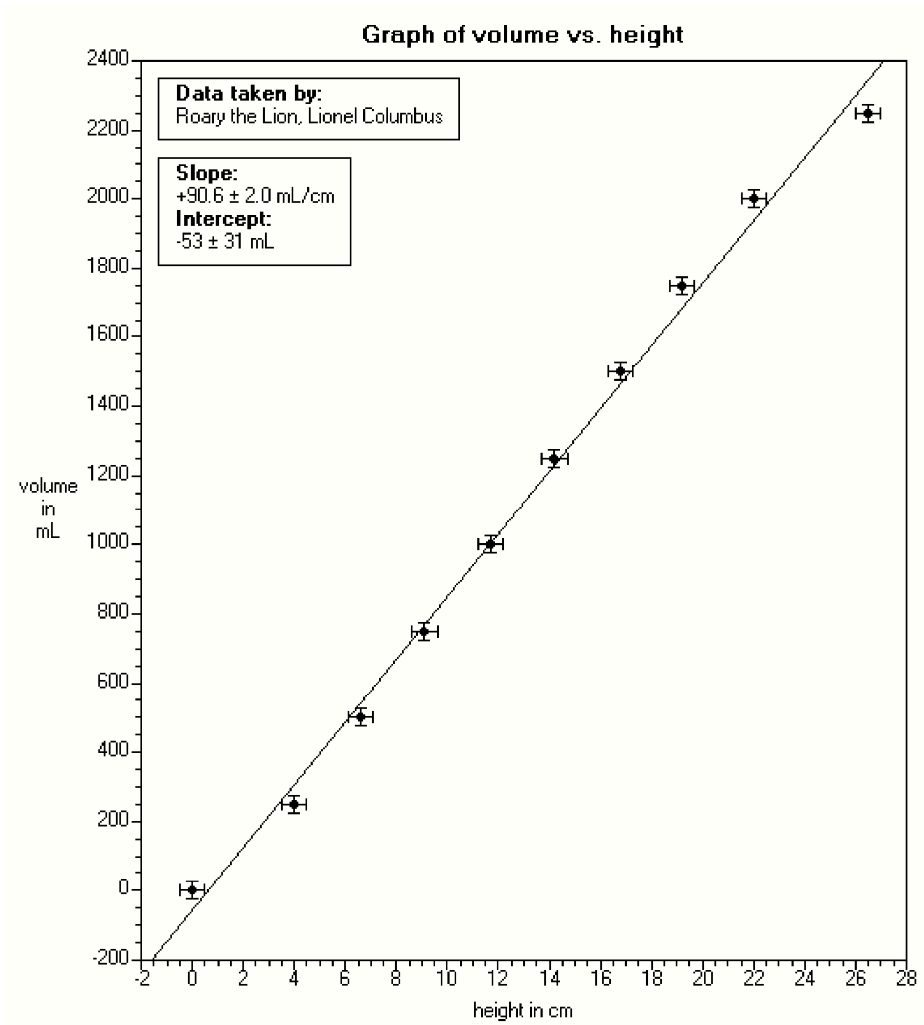
We can compare the value for the circumference calculated from the height-volume data with the value we find from measuring it with a measuring tape.

Raw Data:

Volume filled in (mL) (±25 mL)	**Height of Water Level (cm)** (±0.5 cm)
0	0
250	4.0
500	6.6
750	9.1
1000	11.7
1250	14.2
1500	16.8

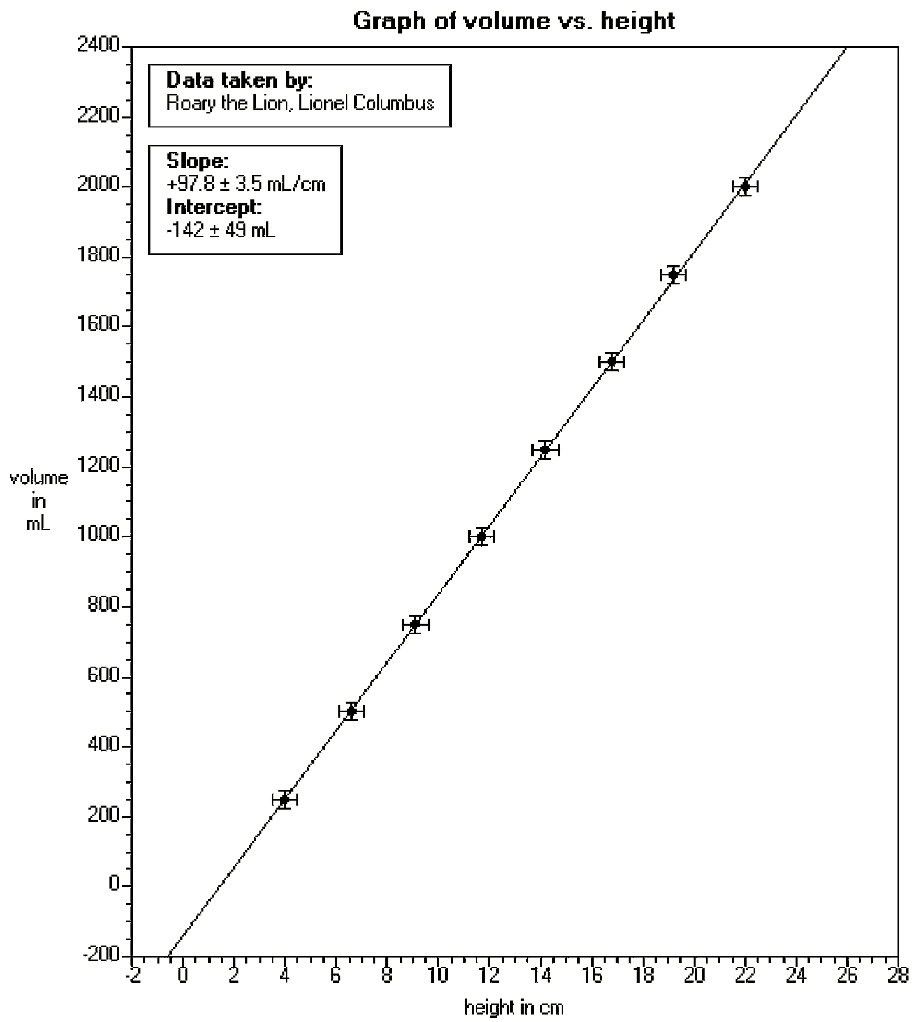
1750	19.2
2000	22.0
2250	26.5

Data Analysis:



Graph of all data with linear fit

The best fit line fits the data pretty well, except for the first and last data points. If we omitted these points (which we should do, because of the non-cylindrical shape of the bottle at these heights), the data points fall on an almost perfect best-fit-line (with a non-zero intercept). All data points fall on the best-fit line within their uncertainty. *{In a real report you could have just drawn a second line on the same graph. That was not done here for computer reasons}*



Graph of data with two points removed to improve fit of the line

For the eight points in the central cylindrical region, the line has

Slope: 97.8 ± 3.5 mL/cm = (97.8 ± 3.5)*10^{-4} m^2
Intercept: 142 ± 49 mL

The uncertainty of these values were found by drawing two additional lines, ones with the maximum and minimum slopes consistent with the error bars on the points. Half of the difference of these two slopes was used as the uncertainty for the slope and likewise for the intercepts.

The slope is equal to the area, so the cross-sectional area of the bottle is 0.0098 m^2 or 98 ± 4 cm^2. Thus the measured circumference is $\sqrt{4\pi * 98cm^2}$ = 35 ± 1 cm. In this case, due to the square root, the relative uncertainty on c is half the relative uncertainty of A.

We measured the bottle to have a circumference of 31.3 ± .5 cm. Our two measurements do not agree within uncertainty. Therefore our random uncertainties are not enough to account for the difference between the two values and there must be a systematic uncertainty that we did not eliminate. One possibility is that we were accidentally adding less than 250 mL each time. That would cause the slope of the line, and consequently the calculated area and circumference, to be larger than it actually is.

Conclusions:

Our expectation of a linear relationship between volume and height seems correct. The data supports this notion very well as the data falls on a straight line in the V-h graph. The fact that the intercept is non-zero (as we would expect) can be accounted for by the indentations at the lower end of the bottle. The slope can be interpreted as the average cross sectional area of the central portion of the bottle and used to calculate the circumference. Our two methods for measuring the circumference were roughly in agreement, but not to within our estimated uncertainty. Either we underestimated the random error associated with measuring the height or volume, or there was a systematic error that we did not anticipate, such as consistently mis-measuring the volume of water being added.