Speed of Sound

For this project, you and your team will work together to *create and execute* an experiment. The goal of this experiment is to measure the speed of sound. You and your team will need to come up with an method for measurement that is both accurate and reproducible. As you design your experiment, think about what makes certain lab approaches more or less effective. How do we combat human error in science?

For this project, you and your team will design and carry out your experiment and then compose your findings in a formal lab report.

A laboratory report has three main functions:

1. To provide a record of the experiments and raw data included in the report,

2. To provide sufficient information to reproduce or extend the data, and

3. To analyze the data, present conclusions and make recommendations based on the experimental work.

General Comments:

The single most important requirement for a laboratory report is clarity. Imagine that your audience is one of your classmates who missed that experiment.

If you are using a word processor for your lab report, then use the spelling and grammar checkers. The grammar check can be annoying because often technical sentences are wordy and complex, but it will help you avoid using too many passive sentences. In general, passive sentences are less understandable. However, grammar check will not assess clarity, and it will ignore simple errors. (I do not doubt there are still mistakes in this document I have run it through spelling and grammar checks.)

Many technical writers prefer to write sentences with passive verbs. A simple example: “The spring constant *k* was found from the slope to be 3.02 N/m.” If you run this sentence through the grammar check, it will tell you that “was found” is a verb in the passive voice. To change this to an active voice you could write: “The spring constant *k* is the slope, 3.02 N/m.” Not every sentence has to be in an active voice. What you want is a report that is readable.

Lab Report Structure:

I. **Cover Sheet:** This page has the title of the class and your period, the title of the experiment, your name, your lab partner’s names, the date that the lab was performed and your teacher’s name.

II. **Abstract:** The purpose of an abstract in a scientific paper is to help a reader decide if your paper is of interest to him/her. (This section is the executive summary in a corporation or government report; it is often the only section that a manager reads.) The abstract should be able to stand by itself, and it should be brief. Generally, it consists of three parts which answer these questions:

i. What did you do? – A statement of the purpose of the experiment, a concise description of the experiment and physics principles investigated.

ii. What were your results? – Highlight the most significant results of the experiment.

iii. What do these results tell you? – Depending on the type of experiment, this is conclusions and implications of the results or it may be lessons learned form the experiment.

- Write the abstract after all the other sections are completed. (You need to know everything in the report before you can write a summary of it.)

III. **Data Sheets:** If your data values are so sloppily recorded that you have to recopy them, then the accuracy of the data is questionable. This fact will be reflected in your laboratory performance score.

- The values that you record on your data sheet must have:

  i. Units (such as kg for kilograms)

  ii. Reasonable uncertainty estimates for given instruments and procedures

  iii. Precision consistent with uncertainty (proper significant digits)

IV. **Graphs:** Use computer software to make graphs. Remember that when plotting data with units, both the slope and intercept of a graph also have units.

V. **Sample Calculations:** Show calculations in a neat and orderly outline form. Include a brief description of the calculation, the equation, numbers from your data substituted into the equation and the result. Do not include the intermediate steps. *Numbers in the sample calculations must agree with what you recorded in your data sheet*. For calculations repeated many times, you only include one sample calculation. Answers should have the proper number of significant figures and units. (It is not necessary to show the calculation for obtaining an average, unless your teacher requests that you do so.)

- Typing the equation into the lab report is not required; it is easier and faster to print these calculations neatly by hand. If you wish to type this section, then use the equation editor in Microsoft Word.

VI. **Discussion of Results:** This is the most important part of the lab report; it is where you analyze the data. (In the future, you may not actually collect data; a lab technician or other people may collect the raw data. Regardless of your discipline, the most challenging and rewarding part of your work will be analyzing the data.)

- Begin the discussion with the experimental purpose and briefly summarize the basic idea of the experiment with emphasis on the measurements you made and transition to discussing the results. State only the key results (with uncertainty and units) quantitatively with numerical values; do not provide intermediate quantities. Your discussion should address questions such as:

  i. What is the relationship between your measurements and your final results?

ii. What trends were observable?

iii. What can you conclude from the graphs that you made?

iv. How did the independent variables affect the dependent variables? (For example, did an increase in a given measured (independent) variable result in an increase or decrease in the associated calculated (dependent) variable?)

- Then describe how your experimental results substantiate/agree with the theory. (This is not a single statement that your results agree or disagree with theory.) When comparison values are available, discuss the agreement using either uncertainty and/or percent differences. This leads into the discussion of the sources of error.

- In your discussion of sources of error, you should discuss all those things that affect your measurement, but which you can't do anything about given the time and equipment constraints of this laboratory. Included in this would be a description of sources of error in your measurement that bias your result (e.g. friction in pulleys that are assumed frictionless in the formula). Your analysis should describe the qualitative effect of each source of error (e.g. friction slowed motion, causing a smaller value of acceleration to be measured) and, where possible, provide an estimate of the magnitude of the errors they could induce. Describe only the prominent sources of error in the experiment. For example, the precision of the triple balance beam, a fraction of a gram, compared to the 250.0 g lab cart is not significant. Your discussion should address questions such as:

  i. Are the deviations due to error/uncertainty in the experimental method, or are they due to idealizations inherent in the theory (or both)?

  ii. If the deviations are due to experimental uncertainties, can you think of ways to decrease the amount of uncertainty?

  iii. If the deviations are due to idealizations in the theory, what factors has the theory neglected to consider? In either case, consider whether your results display systematic or random deviations.

- Include a brief conclusion, summarizing your results

- **Considerations:** Consider this advice to whoever tries to reproduce your experiment. What should they look out for? If you were to do this experiment again, what would you do differently? If you had more time to continue this experiment, what would you add to it?

- **Endnotes:** The report should not be a big production. It should not take hours to write. The objective is to write down the significant details of the experiment, the analysis of the experimental data. A few neatly written pages, including your data sheets will suffice for most experiments.