HOW TO WRITE YOUR PHYSICS 1030L/1040L LAB REPORT

Laboratory work is an essential part of the learning process at this level of physics, and develops the process of science. The classical sequence of the process of science usually begins with an observation. The formation of a hypothesis follows. A scientist might develop a theory that describes the observable phenomenon and can be used to predict the outcome of an experiment to test the hypothesis. The results of experiments help to decide if the scientist's original speculation for the outcome was consistent with derived theory.

During the semester you will perform 11 assignments/experiments, analyze their results, and write and turn in lab reports. The purpose of reporting laboratory results and experiments is to record observations and progress in the endeavor, as well as to present results to the scientific community for peer review and advancement of global scientific understanding of the phenomena. The aim in a scientific report or manuscript is to convey to the reader clearly, concisely, and convincingly, the description of the experimenter's work. Laboratory reports in collegiate settings are an opportunity to practice good communication, and the single most important point is clarity. In almost all cases, the most concise way of saying something is the best, but obscurity just as easily arises from too few words as too many.

Lab Report Format

Proper presentation of your experiments and their results is important. Scientific studies not properly presented are never accepted for peer review in the professional world. In a professional setting, there are defined formats specific to each journal to which you may wish to submit your work. The unique arrangement differs for each, but all have roughly the same parts: background, experimental methods, concise presentation of data (either by graphs or tables), and a succinct statement of results with some discussion regarding the certainty of the results as well as their relevance and relationship to the larger field of study.

For this course, we will adopt a combination of techniques for presenting work in a formal laboratory report and reporting internally in a laboratory notebook. We will treat our lab report as the documented record of all work we have performed for each experiment along with our hypotheses, expected outcomes, results, and thoughts regarding the results. The following sections should be assembled in order for each report in this course:

1. Title of the experiment, date to be performed, experimenter's name, lab partner(s) (if any)	pre-lab
2. Objectives of the experiment	
3. Relevant background	
4. Methods/Apparatus	
5. Experimental data	during lab
6. Calculations and graphs	after lab
7. Results and discussion	

Proper presentation is important to receive full credit. If not assembled correctly, it may result in subtraction of points from your grade. The "style" portion of each lab report grade will be a reflection of the professionalism and readability of the report in the overall judgment of the instructor.

Pre-Lab Work

The pre-lab segment of the lab report is designed to enforce studying and preparation for the experiment before the laboratory session. Print and fill out the pre-lab report pages from the manual.

Goals/Objectives:

The goals of the experiment, be they to observe and describe a phenomenon or to measure a value for a specific quantity, should be stated first. They are the first thing the reader wants to know and should be given in one or two complete sentences.

Theory/Relevant Background:

The function of this section is to give enough background information so that the rest of the report makes sense. It is not to repeat the entire theory that was provided in the lab description for your understanding of the concept. *It should be written in your own words and interpretation; word-for-word duplication and lack of interpretation of the manual is not acceptable and will not earn points toward the lab report grade.* Start with the assumption that the reader of the report, though intelligent and well informed, knows nothing of the specific work described and needs to be brought up to date on the appropriate concepts in the field of the experiment. How much needs to be included? The answer is the minimum that renders the rest of the report understandable.

The best way to achieve this is to first read the lab description, figure out what you will be doing and measuring in reference to the goals of your experiment, and just include what is necessary for that endpoint. Include relevant equations, but a detailed derivation would be unnecessary. Relationships of variables may be important; if you are changing one variable in order to determine the effect on another and a constant, you may want to note the direct or indirect relationship between these variables. Include the application of the background to your particular experiment so that the reader will understand why you are taking certain steps in the experiment.

Apparatus/Procedure/Methods:

Your methods for observation should be stated as concisely as possible. Methods should include the experimental design for each measurement so that the reader can see factors that contribute to the result, but should not degenerate into experimental trivia. This should not be a reproduction of the procedure in the lab description, but it should include parts of the procedure and data analysis and must be *in your own words and interpretation*. Only include what is necessary so that the validity of the experiment can be seen. Don't include: "I will plug in the apparatus." Do include: "I will find a standard deviation of the mean to estimate the uncertainty in my measurements." A diagram of the set-up if warranted and if done right, can be worth 1,000 words.

Laboratory Work

Experimental Data:

During the laboratory session, you should record all work you have performed on the data pages provided with each lab description. The data sheets need to be completely filled out and legible. You will need to keep your data carefully to turn in with your finished lab report.

Calculations:

The calculations section is for the instructor's benefit; for clarity's sake, use labels designed to show for what the calculation is intended. Ideally, you should write down a sample calculation for all steps in the determination of your final result; this only needs to be done for one data point if you repeat the same calculation for a set of data. If you use a spreadsheet program to perform calculations and include a print out, you must still show the calculation for one data point. At the end of each lab description, a list of the specific calculations which will be graded is given.

Calculations have to be typewritten. Units must be carried throught the entire calculation.

You can use Microsoft Equation 3.0 under insert object menu in MS Word 7 for math symbols.

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Graphs:

Graphs must hand plotted, if asked for, or be generated with an appropriate computer program, and should be clear and informative. They must have the following: a title with units, properly labeled coordinate axes with units, clearly marked data points, an equation that best fits the data, and some computer-generated coefficient for the goodness of fit (like R^2 or MSE).
Graphs should fill up an entire page. Please refer to the graphing instructions in "Fundamentals of data, Graphical, and Error Analysis" for more detailed instructions.

After Lab

Results:

Your results section should report only the final outcomes of your experiment. The calculations with intermediate arithmetic values should not be included here, and the methods should not be repeated – this is not a summary. All quantitative values should be rounded properly with their uncertainties marked right beside them, in the format result ± uncertainty (units). In this way, the statement of the result includes some range of confidence that can be used to convince readers of the usefulness of the experimental result. In addition, the value and its uncertainty should be given in a complete sentence, not merely "$g = 9.8 \pm 0.1$ m/s^2".

In the uncertainty, round to only one significant figure, and discard the trailing digits; then round the result to the same decimal place or position. For example, a result such as 9.8145 ± 0.14 m/s^2 would be reported as 9.8 ± 0.1 m/s^2. Only one digit was kept in the uncertainty, and the result was rounded to the same decimal place because if the 8 in the result is uncertain, the 145 is even more uncertain. A more precise result would be reported as 9.795 ± 0.004 m/s^2. The answer and uncertainty must be consistent. A result should not be reported as 9.70361 ± 0.2 m/s^2 nor as 9.7 ± 0.0002 m/s^2.

Units are very important to any result. It would be ambiguous to report: "The distance from UTC to downtown is 8". It is unclear whether the author means 8 miles, 8 meters, 8 minutes, or 8 apples. Similarly, the units of a value of current must be specified as μA, mA, A, etc. The uncertainty needs to be expressed in the same units as the result. Units can be given just once with the uncertainty if the result is written as result ± uncertainty (units).

The results section is also the appropriate place to compare your results to any accepted value for a quantity that may be in the literature, because the reader will be interested. This does not say that your result is "right" or "wrong". It may be appropriate here to discuss the sources of random or systematic error in addition to measurement uncertainty (see "Fundamentals of data, graphical, and error analysis" for more details). This may also be more appropriately addressed in the conclusions section, depending on the particular experiment.

Conclusions:

Conclusions should first state the significance of the experiment and whether or not the objective of the experiment was met (i.e. if the objective was to verify Ohm's law, assess whether your data verifies this law). It is best to talk of appropriateness of applying the theory to your results, not the rightness or wrongness of it. For an experiment that has well-established theory, this theory was most often deducted from an idealized model (under conditions of weightless or frictionless components of the apparatus, lack of thermal noise, etc.). The extent to which the theory is valid to interpret the results of your experiment is your responsibility to determine. If the conditions don't match, a systematic error may have been introduced, and you should try to determine what the systematic error might be.

If the goal of the experiment was to determine some quantity, discuss the uncertainty in your measurement and postulate factors that may have restricted your precision or accuracy. Make sure that your comments make physical sense. In thinking about potential sources of error, consider the degree of control you had over the experiment and statistical fluctuation. For example, in a particle-counting experiment for nuclear physics, background cosmic rays may result in the addition of unwanted counts. Think about whether the experiment was designed to measure a difference that can *only* be caused by the factor under investigation, and not something else which was not controlled. Point out limitations to the work – if you don't, someone else will, which is bound to be more distressing.

You do not need to repeat the procedure (or steps of the experiment) in the conclusion. You should answer any additional questions asked at the end of the lab description if asked to do so by your instructor. As with all sections of the lab report, these need to be formulated into complete sentences rather than a mere duplication of the question and short answer.

The results and conclusions portion of the lab report should be typewritten. Please staple your analysis in order according to the generic lab report format above.