

## Introductory Physics Laboratory Course Information (*Stephen Arnason, Course Director; Office Hours M 4-5 S/3/043*)

Physics 181 is a two-credit laboratory course. **You will do a total of eleven experiments.** The co-requisite or prerequisite is Physics 107 or Physics 113. Course material for this lab is located on the **Physics Website [www.physics.umb.edu](http://www.physics.umb.edu)**. This Website may change during the semester but you will be informed of any changes well before they occur.

### Object of the Laboratory

As a pedagogical tool the physics laboratory is very important. It provides a tangible manifestation of the abstract concepts that are discussed in lecture; an opportunity to connect the theoretical with the real. It also gives students an opportunity to learn to communicate effectively about difficult quantitative concepts. Being able to write a sentence that succinctly describes a phenomenon is a skill that enhances anyone's resume. And finally, the laboratory teaches students to extract meaningful information from numbers. We hope this course achieves these objectives and does so in a way that is fun.

### Schedule and Attendance

Each laboratory section meets once a week. Please carefully examine the course schedule for the exact dates for your section. You are expected to attend the laboratory during the lab time for **your** section. Holidays and other events may effect the day you do a lab in a given week.

If you miss doing an experiment during your regularly scheduled lab section, it is important that you go to another lab section during the week the experiment is done, with both instructors (TA's) permission, **as you will not be able to make up an experiment at the end of the session**. **Please avoid making personal appointments during your regularly scheduled lab time.**

If you have a medical condition which you feel will affect your ability to attend your scheduled labs and do the experiments, you are required to notify your instructor (TA) as soon as possible. In addition, you are required to e-mail Professor Stephen Arnason ([stephen.arnason@umb.edu](mailto:stephen.arnason@umb.edu)), the Lab Director, and notify him of your condition, or contact him if you have any other problem that affects your attendance or problems with the course. Please be proactive in communicating about problems, they are much easier to solve before the semester has ended and grades have been submitted to the registrar.

### Preparation for the Laboratory

Lab material is on the Physics Website at **[www.physics.umb.edu](http://www.physics.umb.edu)**. It is the responsibility of the student to print out all necessary materials (and complete any assignments associated with the experiment, if required) before coming to class. You are expected to have read the lab handout and be prepared for the experiment before coming to the laboratory. The pre-lab test requires one to read and study information about the experiment. This is an important part of the course.

#### The following will be needed for the lab:

1. **A Scientific Calculator capable of doing statistical calculations and linear regression, along with its operator's manual.** You are not required to purchase an expensive graphing calculator. **If you do not have your manual, it is easy to search the web for operating instructions on most calculators, especially instructions on doing linear regression and statistics.**

2. **A long (about 30 cm) transparent plastic ruler. Bookstores should have them. You will need this for the first experiment's graph, and the rest of the semester**

### **Pre-Lab Test**

Associated with each lab is a pre-lab test. The purpose of this is to help you to focus your reading of the lab handout and to prepare you for the analysis you will conduct during the lab itself. The pre-lab test is due at the beginning of the lab. **Pre-lab test which are not submitted at the start of the lab will not have their grades recorded. The pre-lab test is worth 10 points.** Tutors, graders, instructors and lab TAs will not solve problems on this test. You may ask your lab TA (instructor) about this pre-lab test the following week during office hours.

### **Quick Sheet**

At the end of each experiment, you will complete a summary of your lab results. This will allow your instructor an opportunity to review your experimental results in class before you write your laboratory report. This quick sheet will provide a record of your attendance. **The quick sheet is worth 5 points.** This sheet will be given to you during the lab, and it is your responsibility to turn this in to the instructor before you leave. You will not take this sheet with you, so be sure that you leave with your own copy of the information. You will be required to sign this sheet.

### **Laboratory Reports**

A computer generated laboratory report, **which is worth a maximum of 85 points,** is required for each of the eleven experiments. Please refer to the Website for information on attaining access to campus computers if you do not have other access to computers with a word processor. The format of the lab report should not deviate from the guidelines suggested in Appendix I.

One of the objectives of the lab is that you learn to generate a detailed lab report involving the drawing of graphs, data analysis, computations and answers to questions on each experiment. You will cut down a considerable amount of time in doing a lab reports if you do the following:

Complete data computations during the lab period and have your work checked by the instructor before you leave the lab. This requires the completion of the Quick Sheet.

**A late lab report will merit a minimum loss of 20 % a day. Lab reports submitted more than a week late will be graded but no points will be awarded. There will be no exception to this policy except for medical emergencies. The instructor will have the option of taking off points for messy or unorganized lab reports (if we can't read something it is wrong). The cover (first page) of your lab report should include your name, section number and your instructor's name, and all pages of your lab report should be stapled. Graphs for lab reports are done by hand and not by a computer. Excel will be used during the lab.**

**Please note that food, candy and beverages are not allowed in the lab.**

**Students are expected to clean their area when they leave the lab. Items left in the lab, as calculators, will be given to the physics office.**

## **Warning**

***Students should do their own written work. Each lab report should be unique, and not a copy of another person's work. Lab partners should only share data. Each must do their own report. If you submit work that is not your own it will not receive a grade and is grounds for beginning an academic dishonesty case against you. DON'T SUBMIT WORK THAT IS NOT YOUR OWN.***

### **When Laboratory Reports are Due**

**Lab reports are due Monday** the week after you have done the experiment. Your TA will indicate the time your lab reports are due. If there is a Monday holiday reports will be due Tuesday at time determined by your TA. **Make a photocopy, or backup, of your report. You are responsible for all reports even if one is lost after you turn it in. Keep your graded reports as they may be asked for at the end of the semester if there is a problem with grades.**

### **Grading Lab Reports**

Your lab reports will be graded by your lab instructor (TA) on a scale of 0 to 85 points. Lab reports will receive one of five possible grades; failing or F, unacceptable or D, acceptable or C, good or B, and exceptional or A. These will be ascribed numerical scores or 0,55,65,75, and 85 respectively. All penalties for late work will be subtracted from these numerical scores. We will be grading reports on the complete package of what is submitted not on a point by point basis. Neatness and effectiveness of presentation will be important as will the coherent explanations of the physics involved in the experiments. Graphs will be graded on a scale as in appendix I which follows.

The TA will be looking for and considering the following portions of your lab reports. While sections describing the theory and experimental set ups are not required you may find it easier to include them rather than incorporating that information into other parts of your report.

- Title and Objectives/Purpose
- Theory (**optional**)
- Expt. Apparatus & Procedure (**optional**)
- Data with Appropriate Units
- Calculations and Analysis  
Graphs
- Answers to Questions
- Conclusions

For some reports, notably the first two, this breakdown will not apply. Calculations must be shown when required. The instructor will indicate on your reports significant failings. If you cannot resolve a conflict with the instructor regarding grading, consult the lab coordinator. If the problem is still not resolved, contact the course director. Use the office hours, **and not lab time**, to discuss the grading of your reports. Please note that the first lab is worth 100 points as it does not have a pre-lab or quick sheet.

## Test

At the end of the session a closed-book lab test will be given. The test will contain questions where you will make experimental measurements similar to the ones done in the lab. In addition, you will be provided with data which you will use to answer questions. **To prepare for the test, you should be able to do each experiment on your own in the lab.** You will not be working with your lab partner when doing the test. You may bring one 4"x6" crib card for each experiment to assist you in doing the test. You may put whatever you want on these cards, and you can write on both sides. Otherwise, the test is closed-book. **You will be asked to graph data and to perform linear regression with a calculator on the test.** You will not be allowed to use a computer, only your calculator, which cannot be shared during the course of the test. During the test, your instructor will not provide instruction. Use office hours during the course to gain extra experience in equipment operation and data analysis.

## Course Grade

The lab test will determine approximately 25 % of your course grade and the grades on the pre-lab tests, quick sheets and lab reports will determine approximately 70 % of the course grade. The remaining 5% will be used to take into account intangibles such as class participation and peer instruction. How you work with your lab partner matters. The intangibles portion of the grade will be determined by conference between the Lab Director and your TA. **There will be a minimum loss of one letter grade for a deficiency of one laboratory report, and failure of the course for a greater deficiency of reports. MISSING TWO REPORTS RESULTS IN A FAILING GRADE.**

To account for the different grading styles of instructors, students in a lab section will be graded independent of students in other lab sections. If there is a significant variation amongst the grading of the sections we will renormalize the grades of the lab reports at the end of the semester to ensure that you receive a grade equivalent to what you would have received in another section. This can result in grades going both up and down from the strict numerically expected value.

## Appendix I

### Guidelines for Writing Laboratory Report

#### The purpose of your Laboratory Report

Your lab report should be an organized record of your objectives/purposes, data, calculations, graphs, analysis, answers to questions and conclusions. It should be written so that at some later date you can refer to your report and understand it (Perhaps when studying for the lab exam.) The guidelines and the format suggested below will help you create a succinct and useful report.

#### Format of the Report

**You prepare your lab report on a computer**, print your report on 8 ½ x 11 inch white paper, staple it at the upper-left hand corner and put your name, lab section number and laboratory Teaching Assistant's name at the upper-right corner. Graphs must be done by hand, and on millimeter scale graph paper. Put your name on the graphs and staple them to the report. **Be sure to keep a backup copy of your lab report.**

## Organization of the Report

Your report should consist of the following parts, discussed below in detail:

- Title
- Objectives/Purpose
- Theory (Optional, no extra credit)
- Experimental apparatus and procedure (Optional, no extra credit)
- Data with appropriate units and the error in any measurement
- Calculations and Analysis
- Graphs
- Questions
- Conclusions

### 1 Objectives/Purpose

Briefly identify the skills and concepts you intend to learn from doing this experiment and the nominal objectives of the measurements.

### 2 Theory (Optional, no extra credit)

Describe the theory for the experiment. Explain formulas you will use. Avoid simply copying the text from the lab handout. **This part of your lab report should not exceed more than half a page (couple of paragraphs).** This may help you to understand the material.

### 3 Experimental Apparatus, Procedure and Data

#### 3.1 Experimental Apparatus and Procedure (Optional, no extra credit)

Briefly describe the equipment and procedures you will use. Try to be brief. Whenever possible, include sketches and/or diagrams of the apparatus. Include the list of the measuring instruments as well as their description, indicating the smallest amount of physical quantity which they measure.

Summarize the procedure. **Again, do not duplicate text from the lab handout in your report; instead, you may summarize the lab handout text in a few short paragraphs. This part of your lab report should not exceed more than half a page (couple of paragraphs or a bulleted list).**

#### 3.2 Data

**Use the data sheet provided to record your measurements during the experiment.** You may staple your data sheet in your report or lab notebook as a record of your raw data. **Data, however, must also be written into your report.** Use tables labeling each column or row and indicate proper physical units, e.g., centimeters, grams, seconds. Estimate and record the experimental error for reading equipment and measurements— errors are very important. Always retain your raw data and notes. Remember, part of the function of this lab is to teach you the skills required to produce a quality lab report.

## 4 Calculations and Analysis

### 4.1 Calculations:

During the experiment, you may use the calculation sheets which are included at the end of some of the lab handouts. This will allow you and the TA to see if you have done the experiment correctly. **Calculations must also be written (or computer generated) into your lab report.** Enter formulas when you do your calculations. Insert the numbers in the formulas and indicate your results accompanied with the proper units. If there are repetitive calculations, show a sample calculation and put the results of the calculations (always include units) in a table. Pay attention to significant figures. (Retain one more digit than the required number of significant digits to avoid future rounding off errors when values will be used in additional calculations.) Enter your final value using suggested significant figures. **Clearly underline or box the numerical result of a final calculation.**

While you should enumerate the formulas and results of your calculations in the report, a printout of your analyses, which are to be done as an Excel spreadsheet, should be handed in attached to the report.

### 4.2 Analysis:

Any question which you are asked in the laboratory handout which is not in the question section should be answered in this part of the lab report. **Read the handout carefully**, as you are responsible for all questions which are asked. Use this section to comment on your experimental analysis for your required calculations. Especially if there were any problems, including your selection of linear data, when only linear data is required for analysis of your experiment.

## 5 Graphs:

In this laboratory we emphasize the graphical analysis of data. Graphing data is an essential tool in visualizing trends and detecting new phenomena. It is a powerful method for comparing experiment with theory. In addition, graphs will help you identify data points involving gross measurement errors. Too often people who use computers or calculators to analyze their data arrive at erroneous conclusions because they cannot see which data points are far from their expected values. Use drafting grade graph paper and put only one graph on a page (unless indicated to do otherwise). When plotting graphs, give some thought to choosing scales which will **make maximum use of the total area of the graph paper** without sacrificing the ease with which the data can be plotted or the graphs can be read. The labels on both axes should include units. Title your graph. Use the analysis section of the report to comment on data selection. Calculations of the slope of a graph should be done on the graph with the use of linear non-data points. Your origin should always start at the lower left hand corner of the graph. This allows for full use of the 18 x 25 cm graph page. Your origin will not always be required to be (0, 0). The value of your origin depends on the experiment.

### **Grading Graphs (10 Points)**

The following are requirements for graphs, and points associated with each.

1. You must use 75%, or more, of the graph area.      2 points
2. You must use pencil.      1 point

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| 3. Title your graph                          | 1 point  |
| 4. Axes must have name and units             | 1 point  |
| 5. Show the scale used (1cm = x units)       | 1 point  |
| 6. Show the data and line of best fit        | 2 points |
| 7. Equation of the line ( $Y = mx + b$ )     | 1 point  |
| 8. Calculation of slope from non-data points | 1 point  |

### 5.1 Nonlinear Graphs

If your data points generate a nonlinear graph, it is best not to connect them unless you have a French curve. A French-Curve has plastic guides with different curves that allow you to draw a smooth curve, i.e., a curve smooth in slope and smooth in derivatives of the slope. At times it is difficult to analyze or obtain the equation of a nonlinear graph. In such an instance, it is possible, though not always, to manipulate data in such a way as to obtain a linear graph which can be easily interpreted. As for example, in the Free Fall experiment when you plot  $y$  (*displacement*) vs.  $t$  (*time*), you will obtain a curved (parabolic) graph, but if you plotted  $y/t$  vs.  $t$ , you will obtain a straight line. The linearization of data on a graph will be on the final test.

### 5.2 Linear Graphs

Graphic analysis is easy to perform on linear (straight line) graphs. If points on the graph indicate a linear trend, a transparent ruler will help you to draw a straight line so that the points, on the average, fall on both sides of the edge. Once you have a linear graph, it is a simple matter to determine the numerical values of its slope and the intercept. You will be able to relate physical phenomenon to these values of the slope and intercept. When you plot, use small points, otherwise you will introduce errors when reading graphs. Graphs are a useful tool to show the linearity of data. A region of nonlinear data can be excluded in the determination of the slope, especially when selecting data to enter into a calculator for linear regression.

## 6 Questions

Remember to answer the questions which will be found in the question section of the lab handout. You are required to show your calculations.

## 7 Conclusions

This section should have a clear statement of the results of the experiment and the extent to which the results are in agreement with the theory being tested. When the experiment results in a measurement of a constant, e.g., the acceleration due to gravity at the earth's surface,  $g$ , compare it with its established handbook values. Use percent difference for this comparison.

To make this comparison meaningful, you should include the impact of the experimental error (random, systematic and mistakes) on your results. This includes errors in plotting and reading linear graphs when determining their slope and intercept. In addition, please include a statement of what you have learned, a critique of the experiment, and any suggestions you have which you think could improve the experiment or the lab handout.