Physics 270: Experimental Physics

Lecture: Tuesdays, 2 – 3:50 PM
Lab: Thursdays, 2 – 4:50 PM

Instructor: Dr. Uttam Manna
Office: 313C Moulton Hall
Email: umanna@ilstu.edu
You can contact me by e-mail or *by simply stopping by my office while I am there.* I will communicate with the class using e-mail. Please check your e-mail for important messages.

Course Description:

Experiments that demonstrate principles of physics. Emphasis is on experimental techniques, laboratory practices, data analysis, and the quality of written reports. The course is for two credit hours.

Prerequisites: PHY 112 and 220

Texts and Notes:

1. *Experimental Physics Lab Manual*; available for purchase at PIP Printing.
2. *Notes on ReggieNet*; additional lecture and laboratory notes will be provided.
3. *Laboratory Note Book to be maintained by the students*

Goal of the Course:

The goal of the course is to introduce the skill sets required for you to be a professional scientist (experimental, theoretical or computational). You will learn and practice the steps involved that lead to scientific discoveries in the context of experimental science. The specific things for you to learn are:

- Recognizing the key question/s to be addressed in a particular experiment with historical prospective
- Examining various approaches to examining physical phenomena
- Understanding the capability and limitations scientific instruments
- Data acquisition and analysis using computers
- Error analysis and statistical analysis of data
- Journal-quality scientific reporting

Working in Groups:

Students will work in small, assigned groups. The assignments and schedule will be given to students during the first or second week of class.

Each student is responsible for his/her own work. The data collected by each group will be shared, but each student must prepare a unique report, including original graphs produced separately by each student for their report. Anyone copying work from someone else may receive a zero for the report or be asked to submit a new report.

Attendance:

- Attendance will *not* be recorded! However, since the course is required for you to perform *hands-on* experiments in the laboratory and write up lab reports, attending both lecture and lab sessions is required for you to do well.
- Moreover, time in this course is expected to strongly affect your growth as a professional – so attending both the lecture and lab sessions can be valuable in your professional life!

Description of Various Components of the Course

A. Homework:

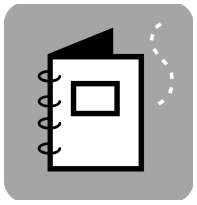
Since the course is designed mainly for you to perform hands-on experiments in the laboratory and write lab reports, there will be no as such homework that are assigned in a traditional lecture class (such as solving numerical problems), *etc*. Instead, you are required to perform the following homework to fulfill the requirements of the course.

- Prepare for the experiments by reading lab manual and note
- Perform data analysis, and write lab reports if there is no adequate time available during the class and lab hours

B. Preparation:

- You must read the experiment description in the lab manual and be knowledgeable with respect to any assigned readings before coming to class to begin the experiment.
- It is highly recommended to read about the physics behind these experiments by consulting various textbooks and online resources. In some cases, additional readings will be provided on ReggienNet.

C. Laboratory Note Book:



- You must maintain a lab notebook for recording data and taking notes while performing experiments - laboratory notes will contribute to 20% of the grade for each experiment.
- You are required to submit copy of relevant pages of the laboratory notebook associated with a particular experiment along with the lab report for each experiment.

Common practices for keeping good lab note book:

- You will use lab notebook to take notes, write experimental procedures, record experimental data, draw graphs and tables etc.
- A loose-leaf notebook is not recommended. The notebook should be kept such that anyone could open it and understand what is written there.
- The notebook will be required to prepare your final report for each experiment. The best way to produce a good final report is to have everything you need readily available in your lab notebook.
- The notebook should contain the original data, analyses that support the results, uncertainties, tables, figures, and calculations.

- Work done in spreadsheets and/or plotting/fitting programs should be documented with descriptions of the calculations performed.
- Any circuit diagrams should be those actually used in the experiment.
- The notebook is not a place to scribble or doodle. It should be professional looking.
- The pages of the notebook should be consecutively numbered. Use page 1 for a table of contents, writing the name of the experiment and the page number on which it begins. All information should be written in ink.
- No pages should be removed at any time. Indicate mistakes with a single line through the incorrect material. Any additions, such as graphs, data sets, etc. should be taped in, so that they will be a permanent addition to the notebook.
- On the first page for each experiment, indicate the date and the names of persons involved in the experiment. On subsequent days, indicate the date before proceeding to write new information.
- When making notes on measurements, properly label the measurement and record numbers with the correct number of significant digits and correct units. Define quantities before they are used. When using equations, perform all algebraic manipulations before inserting the values of the parameters.

D. Lab Reports

For each experiment, there will be a final report that follows the kind of format you might find in manuscripts submitted to a peer-reviewed physics journal. The reports must be prepared using a word processor capable of creating quality scientific equations (such as the equation editor in MS Word). Reports should be single-spaced. The sentences should be grammatically correct and spelling should be checked. The manuscript format should be consistent with the specified in the American Institute for Physics Style Manual at

AMERICAN INSTITUTE OF PHYSICS

https://publishing.aip.org/authors/preparing-your-manuscript

The **title** should match that of the experiment performed, and the list of the persons that performed it should be indicated. Your name should appear first on that list as writer of the report.

The text should contain an **abstract**, a paragraph that gives a short description of the experiment, the reasons for performing it, a short description of the results, and a short conclusion.

The next part of the report is the **Theory** or **Introduction** section. The descriptions in the experimental procedure documents have a detailed theory section. You *should not* reproduce this, but rewrite it and simply put in enough of a description of the theory behind the experiment that anyone reading your report will have a sufficient theoretical basis for understanding the experiment and its results.

All **equations** should be rendered using the equation editor and centered on the line and written using the equation editor in *MS Word*. If you use an equation number, the number is placed in parentheses and is justified to the right margin. If you need assistance on this or any other functionality of *Word* or *Excel*, ask Dr. Marx. Do not use the equation editor to insert scientific notation, subscripts, nor superscripts in text.

The next part of the report will be a description of the **Experimental Procedures** and the equipment used. Again, since the lab description has this in detail, simply describe the equipment

and procedures, and include any wiring diagrams. Also, include any important information that is assumed in the experiment. When including drawings of the apparatus or circuit diagrams, these can be hand drawn. **Do not** write this section like a cookbook as to the procedures to follow or were followed. ***Remember: You are telling a story about the experiment, not telling someone step by step what to do.*** If the procedure calls for simple measurements, give the results in this section when you are describing the procedure. For example, if the procedure calls for making a length measurement, give the result along with its uncertainty. Describe fully how the measurement was made and determined.

For **figures**, include a figure number and a description of the figure (figure caption) below the figure, as shown in the example on the next page. Use *italicized* font for the figure number and description. My preference is that the figure description must be in complete sentences that completely describe the important features of the figure. There should be at least one blank line above and below the figure, which is inserted in the text near its discussion in the body of the report. Numbers written in scientific notation should be in the proper format. Example: 1.23 mm = 1.23×10^{-3} m. *Note: the real multiplication sign and a real minus sign must be used. Both of these symbols are available in Word using the Symbol palette.*

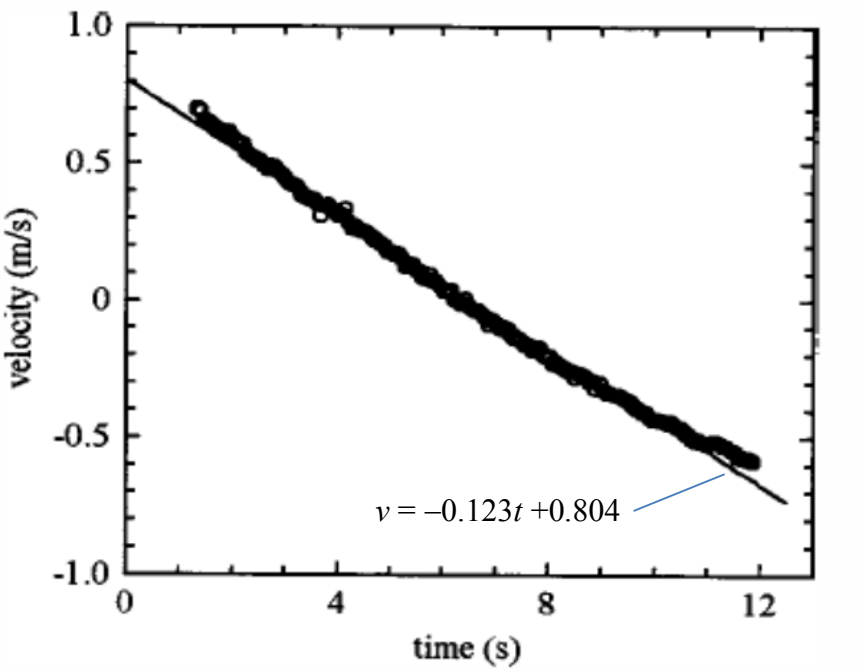


Figure 2. Velocity versus time data is shown using circles for a cart carrying a disk of radius r = 0.080 m. The results of a linear least squares fit are also shown.

The next section is **Results and Discussion**. Here, you present the results and analysis of your experiment in a logical manner. It is important to tell a story about the results. Do not start this section with a figure or tables, rather use text to provide some introductory words or a description of the results found in figures and tables. If possible, the described figure or table should immediately follow the paragraph in which it is described. You should also present any discussion of uncertainties, error analysis, experimental limitations, etc. When estimating random and systematic errors, explain the process by which you arrived at your values. When appropriate, compare your results with expected values and discuss any differences. When describing

differences between experimental and expected values, it isn't good enough to just say "The error was large and probably due to human error." I expect a much more careful analysis of the source of errors and how one might reduce them. Practice using the data handling techniques given in in the data handling section of the course modules and lecture content. Any discussion of error should be quantitative with values that are supported by observations, measurements, and/or calculations.

Tables should be used to organize and present the data in logical order. Tables are labeled using a Roman numeral (such as, Table I) and one or more descriptive sentences. If you get a printout from Excel or other program, the cells should be formatted to give the proper precision of the measurements (for example, 1.500 should not be tabulated as 1.5 and 2.97 should not show up as 2.69581043). The column headers should include the variable and its units. An example is shown below.

Table I. The measured values of current and voltage have been used to determine the resistance using Ohm's law. The observed small increase in the resistance may be due to warming of the resistor.

Current I (mA)	Voltage V (V)	Resistance R (Ω)
2.42(2)	0.112(1)	46.5
12.4(1)	0.578(1)	46.6
36.3(1)	1.695(1)	46.7

Figures that are graphs or plots should have labeled axes with proper units and have a legend. You should include the figure description information as described above, along with the figure number. Error bars should be included when available. Justify your choice of plot or curve fitting (for example, "As shown in Equation 4, the voltage V is expected to decay exponentially with time. Therefore, the data is plotted as log V versus time t to obtain a straight line.").

If a **curve fit** has been used, include the fitting function using the plotted variables on the graph along with any parameters and their associated uncertainties. In your final report, discuss the quality of the fit to the experimental data. If you do use a fitting function, explain why that particular function was used. Unless there is a reason to perform some type of fitting, simply plot the data points with error bars, if appropriate. Graphs must be made in an appropriate scientific graphing program, such as *Kaleidagraph* or *Origin*. Graphs made in Microsoft *Excel* are *unacceptable*.

Next, you will write your **Conclusions**. In this section, reiterate the purposes of the experiment, summarize the results and discussion, and make recommendations for improvements that may be made to the experimental procedure or apparatus, whenever possible.

References - any book, article, or website that is quoted or from which information has been extracted, must be indicated in a references section. Please use the standard methods for references indicated in the AIP style manual

https://publishing.aip.org/authors/preparing-your-manuscript

If you do need to cite the lab write up for the given experiment, please use the following example:

Marx, DT. "Kater Pendulum" in *Experimental Physics: Physics 270 Lab Manual*, Physics Department, Illinois State University, PIP Printing Services, 2016.

Questions - Be sure that any questions in the lab description have been answered either within the text of your report or in a separate section after the references section.

Language

Traditionally, scientific writing uses the past tense and a passive voice to describe experimental activity. I prefer that you use that style. Therefore, avoid using first person words, such as "I," "my," "me," "our," and "we." There are some exceptions to this, but try to maintain formal usage of English as much as possible. See the discussion of this in the AIP Manual. Also, because the audience for published literature is international, the writing should be formal, use proper technical terms, and avoid slang. Sentences should be constructed so that they will not have multiple meanings – simplicity is best.

Proofread your report before turning it in. If possible, ask someone else to proofread it as well. You might even try reading it out loud, because it's a good way to spot problems because you'll know when something doesn't sound right.

Reports must be your own work. The text should be your own words. Members within a group *may not* share text, graphs or data tables. All text and drawings must be the work of the author. **Plagiarism will not be tolerated** and may result in a zero grade for any or all of the parties involved. See these websites for information on this important topic.

http://owl.english.purdue.edu/owl/resource/589/01/

http://english.illinoisstate.edu/rlbroad/archive/teaching/plagiarism.htm

ISU academic dishonesty policies...

http://deanofstudents.illinoisstate.edu/conflict/conduct/code/academic.php

E. Lab Safety

Laboratory safety depends primarily on everyone exercising both caution and common sense to the hazards that exist. Cell phones should be turned off during lab periods. See the class website for specific safety information.

F. Lab Equipment

Laboratory equipment is often difficult to replace or repair. Please exercise care and caution when making electrical connections, adjusting voltages and currents, handling optical components, etc. Any equipment failures/breakages should be reported immediately, so the matter can be fixed as soon as possible.

G. Lab Report Grading

To encourage students to follow journal quality lab report writing and reporting, the following rubric has been devised to evaluate your lab reports. The rubric is set up on 100-point scale. Note that you may receive up to 10 points for showing enthusiasm for the subject matter by using a creative means of analysis, correct additional analyses, or performed additional experimentation beyond that indicated in the lab description. Here is the rubric:

Item	Low Level	Intermediate Level	High Level
	0 – 3 points	4 – 7 points	8 – 10 points
Understanding of the physics involved in the experiment	The report demonstrates little or no understanding of the physics involved in the experiment.	The report demonstrates some understanding of the physics involved in the experiment.	The report demonstrates a higher level of understanding of the physics involved in the experiment.
Title and Abstract	0 – 1 point	2 – 3 points	4 – 5 points
	The report is missing a proper title, list of contributors with author listed first, and/or an incomplete abstract.	The report has a proper title, list of contributors with author listed first, and an incomplete abstract.	The report has a proper title, list of contributors with author listed first, and a complete abstract.
Introduction	0 – 3 points	4 – 7 points	8 – 10 points
	The report has an introduction that an inadequate amount of theory necessary for the reader to fully understand the experiment and interpretation of experimental results.	The report has an introduction that has some of the relevant theory and equations necessary for the reader to fully understand the experiment and interpretation of experimental results.	The report has an introduction that includes all or most of the relevant theory and equations necessary for the reader to fully understand the experiment and interpretation of experimental results.
Results Section	0 – 6 points	7 – 13 points	14 – 20 points
	The report has less-well written text to describe the results of the experiment, but may contain tables and/or graphs that are poorly presented or missing.	The report includes a well-written text to describe the results of the experiment along with tables, correctly presented, and graphs, correctly formatted.	The report includes a substantial amount of well-written text to describe the results of the experiment along with all necessary tables, correctly presented, and graphs, correctly formatted.
Uncertainty Analysis	0 – 3 points	4 – 7 points	8 – 10 points
	The required uncertainty analysis for the experiment has been done poorly or is missing.	The required uncertainty analysis for the experiment has been done and presented to the reader.	The required uncertainty analysis for the experiment has been carefully done and presented in a professional manner. The analysis is clearly presented to the reader.
Conclusions	0 – 1 point	2 – 3 points	4 – 5 points
	The conclusion section is poorly written or missing.	The report has a paragraph summarizing the experiment and findings.	The report contains one or more paragraphs that summarize the experiment and findings. It may also include suggestions for further study and/or reflections on the experiment.

References	0 – 3 points	4 – 7 points	8 – 10 points
	The report includes no references or references that would be of little use to a reader.	The report includes references that are properly formatted, but some may be inadequate.	The report includes references that are properly formatted and are complete.
Notation and Units	0 – 3 points	4 – 7 points	8 – 10 points
	The report includes numerous mistakes in notation and/or units, including omission of units.	The report includes correct notation and units, but there are several mistakes made in these.	The report utilizes the correct notation and units throughout, such that there are few mistakes made in these.
Spelling and Grammar	0 – 3 points	4 – 7 points	8 – 10 points
	The report has numerous errors in spelling and/or grammar to the point of being somewhat unprofessional.	The report has several errors in spelling and/or grammar, but is overall somewhat professionally written. The report is written mostly in passive voice with appropriate use of past tense.	The report has not more than two errors in spelling and/or grammar. The report is written entirely in passive voice with appropriate use of past tense.
Creativity and Enthusiasm	0 – 3 points	4 – 7 points	8 – 10 points
	Good	Very good	Extra-ordinary

Late reports *will be* accepted; however, there may be a score reduction for lateness. Please let Dr. Manna know if you need time beyond the due date and the reason.

Final Exam:

- For the final exam, you will need to produce a report for an "unknown" experiment (an experiment not described in this manual) that will be assigned to you.
- You will need to produce the report by performing literature survey, and reading textbooks and online resources.
- Detailed instructions along with relevant resources will be provided well in advance

Grading

Grades will be recorded in the ReggieNet grade book. You can check there to keep updated on your progress. Please check to make sure that all grades are entered correctly.

Grading Components:

Group Performance	5 %
Lab Report	50 %
Labe Notebook	20 %
Final Exam	25 %

Grading Scale (subject to change):

90 – 100	A
80 – 89.9	B
70 – 79.9	C
60 – 69.9	D
< 60	F