Physics 451: Advanced Physics Laboratory
Fall 2011
MWF 1-1:50 PM
Room: CNS 308
Prerequisite: PHYS 360 (Intermediate Lab)
3 credits

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Office Hours: M,W 2-3 PM, Th 11:00 AM -12:00 PM
and by appointment

Textbooks: **An Introduction to Error Analysis**, 2nd ed., Taylor, University Science Books (required)

Experiments in Modern Physics, 2nd ed., Melissinos, Academic Press (suggested)

Website: http://departments.ithaca.edu/physics/facstaff/mcsullivan/teaching/ph451/

Class Philosophy

This course builds on the knowledge gained in Intermediate Lab and will expand your experimental skills, while introducing you to a variety of different physical phenomena.

The course goals are:

- To further students' knowledge and abilities in error analysis,
- To train students in formal manuscript writing, including: Literature searches, proper citations, placing current work in context, including an explanation and expansion of the theoretical framework of the experiment, and typesetting via LaTeX,
- To teach students to write and/or modify data acquisition programs in Matlab and LabVIEW,
- To teach students experimental design skills: in particular, how to translate an design idea on paper into a working physical experiment, and
- To teach students how to take an experiment from start to finish, including: design and manufacture of experimental apparatus, data acquisition, data analysis, conclusions and future work.

Course Structure

The course catalog describes Physics 451 as follows: "Students are expected to gain a thorough understanding of several experiments carried out during the term, rather than to complete a large number of small projects. Emphasis is placed on independent work." As such, Advanced Laboratory is designed to meet the course goals above through **independent** work on several different experiments.

There will be no formal lecture. I will be in the lab at the times listed for the course, and I expect all students to be present at the start of class on Tuesdays so I can collect lab notebooks. I also expect all students to be in the lab outside of the listed class times (it will take more than the allotted time to complete the experiments). There is no formal textbook, and much of the information required you will have to discover on your own.

You will be required to complete two experiments (discussed in detail below). Grades in this course are based on proposals, lab reports, and lab notebooks (also discussed in detail below). Because this is an experimental course, the lab reports will constitute a major portion of your grade. The lab report checklist and guidelines will be available on the course website.

Grading

The grades in the course will be based on the following items:

Participation:	10%
Lab notebook:	15%
Lab Report 1 draft:	10%
Lab Report 1:	15%
Lab Report 2 proposal:	10%
Lab Report 2 progress check:	10%
Lab Report 2 draft:	10%
Lab Report 2 report:	20%

Here, "participation" is roughly equivalent to time spent in the lab. This is often judged by how often I see you and how often I get questions.

Final grades will be based on the IC grading scale, as follows: A: 90-100, B: 80-89, C: 70-79, D: 60-69, F: <60.

Experiments

In this course you are required to complete two different experiments. For the first experiment, you will pick from a list of experiments supplied by the professor (the list is below). This first experiment is very similar to experiments in PHYS 360 – only now there are no lab guidelines or handouts to help you complete the experiment, and sometimes (often?) the equipment requires some amount of repair. The first experiment will teach you how to conduct an experiment with minimal guidance using existing materials.

For the second experiment, you must design your own experiment. You must first write a proposal (with goals, a budget, and a timeline) and then use that proposal to guide the project. I recommend that the second experiment reflect your interests in some way. For example, students with an interest in astronomy might consider an experiment that uses the resources at our Clinton Ford Observatory; or a student with an interest in materials science might think about way to grow and characterize a new material. The projects will be vetted and approved during the proposal process. This will build on the skills learned in the first experiment, only now you must conduct your own experiment **and** design/build the equipment necessary for the experiment.

Students may work alone or in groups of two for the first experiment. Students must work alone for the senior project.

There is one possible alternative to this schedule. Students who wish to conduct a semester-long senior project may do so. If a student wishes to complete a semester-long project instead of two experiments, then multiple drafts will take the place of the Lab Report 1 and Lab Report 1 Draft.

Possible Experiments

The following lists possible experiments for the first lab.

Mechanics
Stable Kaye Effect
Chaos (torsional pendulum)
Viscosity
Thermodynamics
Critical Opalescence
Linear thermal expansion in metals
Thermal diffusion in metals and insulators
Electrons in solids
Resistivity (eddy current measurement)
Hall Effect in metals
Hall Effect in a germanium semiconductor
Tolman-Stewart experiment
Superconductivity (J_c)
Boltzmann constant k_B (measuring Johnson noise as a function of T)
Optics
Deflection of an I-beam
Normal and Anomalous Zeeman Effects in Mercury
Microwave tunneling
Quantization
Nuclear Magnetic Resonance
Franck-Hertz experiment
Nuclear
Cloud Chambers
Compton Effect

There is another important class of possible experiments not included above: conducting an experiment from PHYS 360 or PHYS 326 that includes a major revision of the experiment. Major revisions include, but are not limited to, taking the original experiment in a completely new direction, writing a lab manual intended for PHYS 360/326 students, or (most importantly) automating the data collection process using MatLab or LabVIEW.

Final Experiment

There is no set list for the final experiment. For your final experiment, I want you to find an experiment, propose it, and complete it. There are any number of interesting experiments in the American Journal of Physics (`http://scitation.aip.org/ajp`) as well as in the recommended text by Mellisinos. The key is to find an interesting experiment that can be done with Ithaca College resources and that somehow ties in with your interests.

This will probably be the most difficult task in the entire course, so please begin looking for a final experiment during the first week!

Proposals

Before you can begin work on the final experiment, you must submit a proposal. The proposal must contain a short description of the experiment, what you will be looking for (both in words and a short mathematical derivation of the physics), and any significant steps that are required to complete the experiment (e.g. machining parts, writing data acquisition software, making samples), a budget, and a timeline for completion of the final experiment.

The proposal is a signal to the professor that you know what you are doing and what you are looking for when you take data. If your proposal is not acceptable, you cannot begin working on the experiment – but note the due date for the report **will not** change.

All scientists must write proposals and have them evaluated, so this is good practice for students. I will evaluate the proposals in a manner similar to official proposal evaluations (i.e. how my **own** proposals are evaluated) with rankings of Excellent, Very Good, Good, Fair, and Poor. The evaluation criteria (as borrowed from the NSF and Research Corporation) are as follows:

⋆ **Significance**. This usually refers to scientific significance. What will your experiment yield scientifically? Because this is a course, this significance can be extended in several directions, if desired. The significance can be scientific, educational, or add to the infrastructure or capabilities of the department and/or school. Moreover, the significance can be to you, the student, or the department, or the College, or even further beyond.

⋆ **Intellectual Merit**. This usually refers to what you will add to the general scientific knowledge base. This can also be true for your final experiment, but you must justify your proposal's merit as you see fit. One possible avenue is what you will learn from the experiment.

⋆ **Feasibility**. Is your proposed experiment feasible with given materials (or materials the department can purchase) and within the allotted time frame? What are the steps you will take to ensure it is completed? Here can be a good place to lay out the theory behind the experiment to prove that what you are trying to measure is indeed feasible. The budget and timeline will help in scoring will in this category.

⋆ **Expected Outcomes**. What do you expect to find? For example, what type of curve? If you do an experiment like μ_o, it's a line of current squared vs. mass, the slope of which will give you μ_o. Or it can be a description of a certain curve of a measurement of something that is not a fundamental parameter. These outcomes should come directly from a discussion of the theory. Whether or not your experiment was successful will be based on the expected outcomes.

⋆ **Overall**. The overall proposal is given a rating. This encompasses all the other categories and also covers clarity, detail, depth, English grammar, punctuation, etc.

Lab Reports

Each experiment will culminate in a lab report. The lab reports will be graded using the same rubric as PHYS 360 (Intermediate Lab), given below. The lab reports should follow the structure used by experimental papers in the American Journal of Physics. The goal is to write a paper that your peers (fellow students and other physicists) can read and understand. A short explanation and guideline to the reports follows below.

When you hand in your lab, you must turn in both a hard copy and send me a .pdf version of the lab via email. Lab reports that are late will be docked four points (of 40) each school day it is late. Lab reports more than 10 days late will not be graded.

Category	**Points**	Excellent (100%)	Fair (70%)	Poor (20%)	No Credit (0%)
Science					
Title, date, authors (include lab partner here)	1				
Quality of laboratory work	4				
Abstract	1				
Experimental goals	2				

Summary of the theory, with any necessary diagrams	3				
Diagram and description of the equipment	2				
Uncertainty estimates and justification	3				
Units	1				
Modeling/Curve fitting, residuals	2				
Figures (captions, error bars, etc.)	2				
Data Analysis	3				
Conclusion	1				
Subtotal	25				
Communication					
Experimental motivation and background	3				
Presentation of the data	1				
Results	2				
References	3				
Organization and clarity	2				
Neatness/syntax/spelling	1				
Overall	3				
TOTAL	40				

Abstract: The abstract is a very short description of the entire paper. You should say what you measured, what your results were, and what they mean in as short a space as possible. Consequently, the abstract is best written after you have written the rest of the report. The abstract is short (fewer than 200 words), and conveys the essential information regarding the experiment. A sample abstract from the University of Maryland:

> "The A-technique was employed to measured the B-parameter in System C. Under conditions D, we find values for the B-parameter of XXX±YY m/s. These values imply Z."

Introduction: The introduction is where you describe the situation that led to you perform the measurement (the motivation). In a real physics paper, this section is frequently historical, referring to recent results that led to new questions or caused some earlier conclusions to be thought invalid (the background). The idea is to state clearly the nature of the problem, and how your measurements will help to clear it up (experimental goals).

Theory: Describe in broad strokes the important physical principles and how they manifest themselves in the experiment. You must explain this both in English and mathematically. For the math, almost all of the algebra steps can be omitted. Usually the theory section includes a small diagram or sketch to help illustrate the physics.

Experiment: In this section you should describe what you did and how you did it. It is also important to include any equipment you used and any unusual techniques you used. This section must include your own (i.e., not from the web) drawing or diagram of the equipment and a description of how it works (electrically, mechanically, etc.).

Results: You must present the data in the results section. If your data consisted of only a few points, it will probably be easiest to present these data in a table. Usually, the best method is to present your data in a **figure**. Most physicists look at the figures in a paper first, as such, your figures should completely describe the experiment and your results. Be wary of too few or too many figures. Figures are perhaps the most important part of the whole paper, and many people (present author not excepted) create the figures first and write the paper around the figures.

Your data must also include a discussion of uncertainties (leading to error bars in the figure). Include uncertainty in any number you present in the paper. You should discuss and show (where applicable) where your uncertainty came from.

Here you should also present the results of any curve fitting or modeling you did. Discuss any interesting and/or prominent features of the model. Also plot your residuals if possible, or state the value of χ^2.

Finally, all of these elements should be tied together with a compelling narrative. This is not a throw-away section, but rather where you explain In English words what your data shows and what you have determined.

Conclusions: The conclusion should demonstrate the meaning of your results, i.e. what they imply about the physics of the phenomenon. Did the model fit the data as expected? Do your data agree with others? How do the results compare? Here you should state future work.

References: List any references used for the experiment and report. These references should be footnoted in the report.

- **Typsetting via LaTeX:**

All lab reports must be written using the LaTeX typesetting language using REVTeX 4 style (the accepted style of the American Physical Society). Reports should be two-column single-spaced.

For those unfamiliar with LaTeX, it is a text-based (the "TeX" part) typesetting language that allows a swift and easy way to make good-looking scientific documents. The way the documents look is based on a style file. We will be using the style files of the American Physical Society (the "REVTeX 4" part). For a beginner's guide to LaTeX, check out this page: `http://www.tug.org/begin.html`. For more information about REVTeX 4 and example files, you can check out the APS website:
`http://authors.aps.org/revtex4/`.

Perhaps the easiest way to learn LaTeX is to take an existing document and modify it. I have included on the course website the .tex file and resulting .pdf for a recently written paper. I suggest you use this as a template and replace it with your text and figures.

Turning the text-based .tex file into a good-looking .pdf file requires a compiler. There are many free compilers on the web and the student room computers all have the compiler WinEdt on them, so you can always compile your reports on the student room computers.

In order to include figures in your reports, they must be in Encasulated PostScript format (.eps). MatLab can automatically make .eps figures, so I recommend you use MatLab for data analysis.

- **Writing your own lab report:**

For the first experiment, you may work in groups of two, which often helps lab work move faster an easier. Working as a group will allow you to have someone to talk to, work with, and bounce ideas off, and is the most efficient method of getting things done. As such, I expect lab partners to have identical data and identical errors.

When writing the lab report, you are to work **alone** and do your **own** work. You may consult with your lab partner if you are having problems, but everything in your lab report must be your own work. You and your lab partner will have identical data but may come to different conclusions. You should create your own figures, diagrams, and text. Any shared diagrams or figures (or text, obviously) will be considered plagiarism and will be treated as such (see below).

- **Writing Drafts:**

You are required to submit drafts of your reports. These will be graded using the same rubric from Physic 360. Because it is a draft, you are not expected to have completed the report, but the more complete it is, the better. At a minimum, I expect you to have completed the following sections: Introduction / Background, Experiment / Methods, and Theory.

Progress Check

During the course of the second lab experiment, all students will be required to give an oral report ($\sim$10 minutes) on their progress. I will compare your progress with your timeline in your proposal. Deviations from the timeline are allowed for unforseen complications and should be clearly justified during the progress check.

Uncertainty and Error Analysis

Uncertainty and error analysis is one of the skills vital to physicists, scientists, and the public in general, and it was emphasized in the prerequisites of this course. I expect all students in this course to be familiar with error analysis and to use it (correctly) in their lab reports. Please use the required text (Taylor, 2nd ed.) as your guide for correctly using error analysis. I will not review error analysis for you, so please make sure you ask me if you have any questions regarding the correct way to include error in your lab reports. A full error analysis is required for every lab report.

Lab Notebooks

Taking good notes is vital in experimental physics. As such, you are **required** to get a bound lab notebook. You can use your notebook from PHYS 360/326 or see Jill in the Physics office for a new notebook. Unlike Intermediate Lab, I will not randomly collect notebooks. It will be the student's responsibility to get me his/her notebook **at least** four times each semester, with at least three class periods between each grading. I will grade your lab notebook according to the checklist given out in Physics 360.

Keeping a well-organized notebook will help you when you come to analyze the data and figure out exactly what you did, and why, and as such, is a skill vital to experimental physics.

The lab checklist and guidelines are posted on the website. Because you can hand in the notebook when you want to, I fully expect all students to get 100% on the lab notebooks.

Attendance

Students are not required to attend class on the scheduled meeting days. All students will have key card access to CNS 308 and CNS 211, and I expect all students to be in the lab working outside of the class periods. Nonetheless, I urge all students to attend class, as the class periods are the best times to find me and ask questions.

Academic Honesty

Students are expected to adhere to Ithaca College's Code of Conduct (see http://www.ithaca.edu/attorney/policies/vol7/Volume_7-70104.htm). Any students caught cheating (whether they are currently enrolled in this class or not) will be disciplined according to Ithaca College guidelines.

In the scope of this class, cheating can include: Not handing in your own work on the lab report (copying from your partner), copying your lab report from the web or other resource, fabricating data, or fabricating modeling parameters, just to name a few. See the notes about writing your own lab report above.

Other notes:

- Accommodations will be made for students with documented learning or physical disabilities
- I will send out occasional emails to the entire class to their *Ithaca College* email addresses, so you must check them regularly.
- Final grades are FINAL – no work may be handed in for additional credit after the final exam.

Due Dates:

Below is the schedule for assignments. This schedule is subject to change. All assignments (unless noted) are due at 4 PM.

Assignment	Due Date
Lab Report 1 Draft	Wednesday Sept. 21
Lab Report 1	Wednesday, Oct. 5
Lab 2 Proposal	Wednesday, Oct. 19
Lab Report 2 Progress Check	Friday, Nov. 18 (in class)
Lab Report 2 Draft	Wednesday, Nov. 30
Lab Report 2	Wednesday, Dec. 21, **1 PM**

Last revised on August 9, 2011.