Physics 360: Advanced Laboratory I
Spring 2009
TTh 2:35 - 3:50 PM
Room: CNS 308

Professors: Matthew C. Sullivan and Dan Briotta
Office: CNS 262 or CNS 278 (lab); CNS 268
Phone: 274-3964; 274-3965
email: mcsullivan@ithaca.edu; briotta@ithaca.edu

Office Hours: M/W 10-11AM, Th 11 AM - 12 PM
and by appointment

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

Website: http://departments.ithaca.edu/physics/facstaff/mcsullivan/ph360/

Class Philosophy

This course serves to continue to develop the experimental skills introduced in Freshman Lab, expanding these skills and using them in a variety of different physical phenomena.

The course goals are:

• To further students' knowledge and abilities in error analysis, including: error propagation, mean and standard deviation, least squares fitting, weighted averages, normal distribution, chi-squared,

• To train students in data collection, analysis, and presentation (graphing) via Matlab

• To teach students how to summarize experiments in project report format, including a basic understanding and explanation of the theoretical framework of the experiment,

• To learn computerized data acquisition via Matlab, where programs can be modified by the students,

• To teach students the importance of a lab notebook, and how to use it properly,

• To give students experience with a variety of different experiments in various physical phenomena, including "canonical" experiments, and

• To train students to work independently with modern experimental equipment.

Course Structure

Much of the work in Physics 360 will be independent work. As such, I will expect students to be in the lab outside of class times. In fact, there is no way to complete this course if you are only in the lab during class times. Much of class time will be devoted to working on your individual experiments, and as such, will not be a formal, structured lecture. This means that you are free to use class time as you like.

There are exceptions to this general rule. During the first half of the semester, I will be using some class time to lecture on error analysis and error propagation, and there will be homeworks assigned from the textbook to cover this material. One class period will be used for an exam that covers error analysis. Finally, I expect all students to be in class at the start on Tuesdays, and I will collect lab notebooks from students at random to be graded at this time.

During the course of the semester, you will complete roughly six experiments in different areas of physics. The first five experiments I will choose, and afterwards, you can choose the experiment that interests you most.

The final lab report will also include an 8-minute presentation on the experiment or another experiment from earlier in the semester. If you have not given a presentation before, please ask your instructors for help. Also, attending the seminars will give you a good idea of what makes a good and a bad presentation.

Grading

The grades in the course will be based primarily on the lab reports, and secondarily on the lab notebooks, on the breakdown below:

Participation:	5%
Homework:	15%
Midterm Exam:	10%
Lab Notebook:	14%
Technical reports (3 labs):	7% each
First full lab report:	8%
Second full lab report:	10%
Final Lab report:	12%
Presentation:	5%

Here, "participation" is roughly equivalent to time spent in the lab.

The homework and exam refer to homeworks on error analysis and an exam on error analysis.

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 six different experiments. Nearly all of the experiments will be from the "Advanced Lab I" list of experiments. For the first five experiments, I will decide which experiments you do, for the last experiment, you will choose which experiment is most interesting to you. I have included the Advanced Lab I list as well as the Advanced Lab II list – ambitious students my attempt one of the experiments on the Advanced Lab II list.

The experiments are grouped according to category. These categories are used more formally in Advanced Lab II, and can be ignored here.

Students may work alone or in groups of two. At the beginning, I will assign lab partners. Towards the end, you may choose your own lab partner. If you decide to work in groups, you may not work with the same lab partner more than once.

Lab due dates are included in the schedule.

• Advanced Lab I Experiments

Mechanics
Coefficient of Restitution
Cavendish balance (measuring G)
Rotational drag (linear and quadratic)
Viscosity
Electrodynamics
Permittivity of free space (measuring ϵ_o)
Permeability of free space (measuring μ_o)

Speed of light (electronic timing)
Speed of light (Fizeau mirror)
Millikan oil drop (measuring e)
Thermodynamics
Ratio of Heat Capacities (C_p/C_V)
Thermal conductivity
Thermal diffusion
Electrons in solids
Superconductivity (T_c)
Boltzmann constant k_B (measuring Johnson noise as a function of R)
Resistivity via eddy currents
Optics
Index of refraction of air
X-ray diffraction
Measuring elemental spectra
Interference and diffraction of microwaves
Quantization
Photoelectric effect (h/e)
Ratio of e/m
Nuclear
Radioactive decay and counting statistics
Half-life of ^{137}Ba

- **Advanced Lab II Experiments**

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
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 one other choice for your final experiment of the semester: You may return to an experiment you conducted earlier in the semester and re-do and/or revise the experiment. This allows you to take what you have learned and improve on your original data or to take the original experiment in a completely new direction. You may also return to an earlier experiment and write a lab manual intended for other Adv. Lab I students, or write software automating the data collection process using MatLab.

Lab Reports

The largest portion of the grade in this course will be based on the lab reports. Each lab report will be graded out of 35 points.

The lab reports will be graded on the scale 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.

The grading scale is split into two rough pieces: How well the science is done (e.g., data collected, theory understood, data analyzed, and conclusions), and and how well the results and experiment are communicated (e.g., background, introduction, clear and concise write-up).

Lab reports will be graded by both Profs. Sullivan and Briotta, divided by experiment.

CATEGORY	**POINTS**
Science	
Title, date, authors (include lab partner here)	1
Quality of laboratory work	2
Abstract	1
Experimental goals	2
Summary of the theory, with any necessary diagrams	3
Uncertainty estimates and justification	3
Units	1
Modeling/Curve fitting, residuals	2
Figures (captions, error bars, etc.)	2
Results	3
Conclusion	1
Communication	
Experimental motivation and background	3
Presentation of the data	1
Data Analysis	2
References	2
Organization and clarity	2
Neatness/syntax/spelling	1
Overall	3
TOTAL	35

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 a 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.

- **Technical Reports:**

Technical reports will be judged on only the criteria listed under the "Science" portion of the grade sheet. Technical reports are shorter than full lab reports. They contain nearly all of the important information (e.g., theory, figures, error analysis, results), but the emphasis is on the science – and doing the science correctly and completely – rather than communicating the science. Moreover, references are not required for technical reports.

The second, third, and fifth (of six) experiments will be written as technical reports.

- **Typsetting Lab Reports**

All lab reports must be typed and all images must be embedded into the document. All equations must be written using Microsoft Equation Editor or a similar equation package.

Although not required, it is recommended that you learn to use LaTeX to write your reports. Students considering taking Advanced Lab II are highly advised to start learning LaTeX now, as it is required in Advanced Lab II. It is again recommended that you use 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.

- **Lab Report Due dates:**

Lab report due dates are listed in the schedule. Lab reports that are late will be docked **three points** (of 35) each school day it is late. Lab reports more than 10 days late will not be graded. If you complete a lab early, you may hand in the lab report and immediately begin working on another experiment (provided the experiment is not in use by another group). **Note:** This is a very good way to get ahead during the semester.

Every student is allowed one extension of a lab until the next Monday at 4 PM, giving you the weekend to complete your lab report. This is your only get-out-of-jail-free card, so use it wisely!

The final lab report is due on the day of our final, due at the end of our final exam time. For the final lab report, late lab reports will not be accepted.

- **Writing your own lab report:**

I strongly suggest you work in groups to help 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 very 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).

Uncertainty and Error Analysis

Uncertainty and error analysis is one of the skills vital to physicists, scientists, and the public in general, and it is emphasized in this course. Error analysis is required for **every** lab report or technical report. As the start, we will only expect you to use the error analysis you have learned in previous courses (PHYS

120 and PHYS 217). As we learn more and more topics in error analysis, we expect you to begin using those techniques immediately. Please use the required text (Taylor, 2nd ed.) as your guide for correctly using error analysis.

To help you learn error analysis, Prof. Sullivan will be lecturing the first five weeks on error analysis. There will be weekly homeworks on error analysis with problems taken from the required text. Prof. Briotta will grade the error analysis homeworks. Finally, shortly before spring break, there will be a midterm exam on error analysis (graded by Prof. Sullivan).

Lab Notebooks

Taking good notes is vital in experimental physics. As such, you are **required** to get a bound lab notebook. You can see Rebecca in the Physics office for this notebook. Each class period we will collect a lab notebook from one student chosen at random and it will be graded according to a checklist that will be handed out on the first day of class (and is also posted on the website). Every student will have his or her notebook checked 4 to 5 times in the semester.

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. Prof. Briotta will grade the lab notebooks.

Presentation

The final lab report will also include an 8-minute presentation on the experiment or on an experiment conducted earlier in the semester. If you have not given a presentation before, please ask your instructors for help. Attending the seminars will give you a good idea of what makes a good and a bad presentation.

Your presentation should be 8 minutes long, and you should use about a minute per slide. Here is a rough outline of your presentation:

Slide 0	Title, who, when, course name, a picture of you
Slide 1	Background and history (if applicable)
Slides 2-3	Theory. Derive the equations you will use.
Slide 4	Experimental Apparatus. With pictures and/or diagrams.
Slide 5	Data Presentation. Usually presented as a line of some sort.
Slides 6-7	Data Analysis. Using the slope of the line to find what you are looking for.
Slide 8	Error Analysis.
Slide 9	Results and Conclusion. Include error bars.

Attendance

All students are required to attend class on the scheduled meeting days. However, if students have other commitments, they are not required to stay the full lab period. All students will have key card access to CNS 308 and CSN 211, as I expect all students to be in the lab working outside of the class period. Nonetheless, the class periods are the best times to find Profs. Sullivan and Briotta and ask questions.

If you are absent on a day that your lab notebook was chosen to be graded, you will receive a zero for that particular day.

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.

Course Outline:

Below is a rough outline of the course. There will be modifications to this outline depending on how fast we cover the material.

Error Analysis Schedule:

Week No.	Class Days	Reading
1	Jan 20,22	Definitions, Motivations
2	Jan 27,29	Writing and using uncertainties, graphing
3	Feb 3,5	Error Propagation
4	Feb 10,12	Statistical analysis
5	Feb 17,19	Normal Distribution
6	Feb 24,26	Least Squares Fitting
7	Mar 3, 5	**Midterm March 3 during class**

Due Dates:

Below is the schedule for assignments. This schedule is subject to change.

Assignment	Due Date
Problem Set 1	Friday Jan. 30, 4 PM
Lab 1 (full)	Wednesday, Feb. 4, 4 PM
Problem Set 2	Friday Feb. 6, 4 PM
Problem Set 3	Friday Feb. 13, 4 PM
Lab 2 (Tech. report)	Wednesday, Feb. 18, 4 PM
Problem Set 4	Friday Feb. 20, 4 PM
Problem Set 5	Friday Feb. 27, 4 PM
Lab 3 (Tech. report)	Wednesday, March 18, 4 PM
Lab 4 (full)	Wednesday, April 1, 4 PM
Lab 5 (Tech. report)	Wednesday, April 15, 4 PM
Presentation Draft	Wednesday, April 29, 4 PM
Lab 6 (full) and Final Presentations	Thursday, May 7, **1:30 - 4 PM**

Last revised on January 19, 2009.