Physics 231
Experimental Physics I
Prof. Donald A. Smith

dsmith4@guilford.edu

Fall 2009
Office Hours: Frank 234B (x2162), TF 11:30-12:30, T 15:30-17:30, R 14:30-16:30
http://www.guilford.edu/physics/231

The universe does not exist 'out there,' independent of us. We are inescapably involved in bringing about that which appears to be happening. We are not only observers. We are participators.
– John Wheeler

1 Course Outline and Philosophy

In this course, we will advance your knowledge of and skill at experimental physics. You have completed 121/122, which has given you much practice with data-taking tools, equipment, and physical laws. Now we will take it to the next level. The experiments will be more complicated, and you will be expected to display a more sophisticated understanding of your work.

We will pay more attention to uncertainties and repeatability. We will also examine the strengths and flaws of both equipment and procedure, to enhance your understanding of experiment design and how to account for and control variables. You will begin keeping a lab notebook, and you will learn how to keep a useful log in that book.

In Physics 121/122 you learned a lot about scientific writing. However, an equally important method of conveying results to colleagues and the public is through oral prsentations. In this course, you will develop your skills at public speaking through oral reports that will mimic professional presentations you might give at a conference of practicing scientists.

We will also play with toys and have fun with lasers.

2 Course Requirements

2.1 Six Experiments

The primary requirement for the course will be to complete six experiments chosen from a list of over twenty possibilities. The first twenty options are displayed in Table 1 roughly in order of difficulty and/or complexity. This table is divided into five rows, each of which represents a primary topic of physics: mechanics, thermodynamics, electricity/magnetism, light/optics, and quantum/particle physics. These experiments are meant to be relatively simple, but often subtle, ways to test relationships between quantities and/or measure specific physical properties of an object or a system. Further experiments are listed in a larger version of Table 1 on the course web page.

Each student will be expected, by the end of the term, to have completed at least one experiment from each row. Experiments from one row may not be substituted for experiments from another row. Your sixth experiment can be any experiment you like. You may not perform a second experiment from a given row unless you have already completed one from each other row. You may choose any experiments you wish – they do not need to be done in any particular order, nor does one group doing an experiment preclude other groups from performing the same experiment later in the semester. However, it is unlikely that we will have the equipment to support two groups working on the same experiment at the same time.

You will perform experiments in pairs. Solo work is not recommended, as it is important to share the workload, and it is almost always useful to have someone off which you can bounce your ideas, to decrease your chances of traveling far down a mistaken path. Only one student gives the oral presentation (see section 2.2) on behalf of each pair. The presenting student must be the student of the pair who has presented fewer times already. If both students in a pair have presented the same number of times, students may choose who gives the presentation. Each student must present one of his/her talks to the Department seminar (see section 3), regardless of partnering. Each student must also keep an individual lab notebook (see section 5).

A tentative schedule of talks and pairings has been posted to the course web page. This schedule ensures that no two partners work together twice, and that there is sufficient time between presentations by the same individual. The dates are currently assigned assuming that each experiment will take two weeks, so that there will be time to complete six experiments in the 15-week semester. The next experiment for a lab group must be chosen no later than the first day when one of the lab partners gives a presentation. The first experiments will be chosen on the first day of class. At the time when an experiment is chosen, it may be possible (time permitting) to postpone a presentation date by one week, if that experiment is particularly challenging. Once a due date is set, I will change the color of the date on the web page. This flexibility, combined with the goal of having different lab partners, means that you may be working on more than one experiment at a given time. It will be crucial to plan your time efficiently and effectively.

Once these six experiments have been completed, if there is time remaining, students may complete additional experiments for extra credit. The partnering scheme allows for a seventh set of partners before you must repeat a team-up. Your final grade for the course will be based on the six highest grades you receive. See section 6 for more information on grading policies.

The course web site also contains a list of other possible experiments that you might try beyond the scope of the basic twenty. The experiments in Table 1 are experiments that I know we have the equipment to perform. The experiments on the secondary list are ones that you will have to put some extra effort into designing. Designing new experiments can be a very rewarding experience, so I enthusiastically encourage you to consider trying it.

If you want to do an experiment that is neither in Table 1 nor listed on the web site, I will entertain proposals for other ideas. You may ask your own questions or read back issues of The Physics Teacher journal (available on-line or from Don) for ideas. Proposals must be written in proper format according to Physics Department guidelines. Funds are available to purchase equipment we do not currently have. Because planning experiments and ordering equipment takes time, make sure you begin designing a new experiment early, and continue working on other, listed experiments while you do the paperwork for your new experiment. Talk to me at

all stages of the process to ensure you stay on track.

The course web site will contain a page on each experiment. These pages will give some background material, contain links to other sites with useful information about the experiment (if any), and a short description of the task set to you to complete the experiment. There may be a brief description of how to use some of the more complex equipment or unfamiliar software, but there will not be detailed instructions. It is important that you not think of science as just following someone else's instructions. Although many people have already done these particular experiments, soon you will begin doing your own experiments, and so it is important to develop the skills and initiative you will need when there is no instruction manual. That said, the manuals for most of the equipment we have are in the file cabinet in the advanced lab. You will have to do your own research to read about the background physics until you understand it. Feel free to use books from the library, the DRL, and the physics office, as well as any reliable on-line sources you can find. Never trust a source at face value without working it out yourself.

2.2 Oral Presentations

In Physics 121/122, we emphasized using the written word to convey the results of your experiments, because published journal articles are still the primary means by which scientific results are disseminated within the community. The second-most-important means of communication is through oral reports: at a physics conference, the scientists bringing the most important results are usually invited to give talks. It is therefore just as important that you can convey your understanding through speech as well as through writing.

Once your team has completed an experiment, one team member must give a ten-minute oral report on your results to the class. This report will be accompanied by a PowerPoint (or Keynote) electronic presentation. We will go over in class how to construct an excellent PowerPoint presentation (and how to make a terrible one). Whichever partner has given fewer presentations must be the one to present (the presenter will be chosen when the experiment is selected). Both team members will receive the same overall grade on the experiment.

If you are not satisfied with your grade on an experiment, you may give the presentation again. The new grade will replace the old. Presentations may be repeated as often as you like. The repeated presentations must be given by the same student who gave the original presentation – you may not switch to your lab partner.

The oral presentations will be videotaped, and in order to receive your grade, the speaker must meet with me some time during the week (that is, by Friday afternoon following the presentation) to view the video of your talk and go over your strengths and weaknesses. Peer evaluations will also be used as a form of feedback, but the final grade will be based on the instructors evaluation. Failure to meet with me by the Friday afternoon of that week will result in a zero grade for that experiment, and the presentation may not be repeated. Remember to schedule a meeting before you leave class on the day you give your presentation.

Table 1: Twenty Available Experiments from Which to Choose

Mechanics	Speed of Sound	Modulus of Steel	Mechanical Resonance	Ang. Momentum
Thermo	Absolute Zero	Boyles Law	Stefans Law	Latent Heat
E and M	Magnetic Force	Magnetic Moment	Current Into Heat	Mag. Suscep. of Al
Quantum	q/m ratio of e^-	Millikan Oil Drop	Compton Scattering	Photoelectric Effect
Light	λ of Laser	n of Prism	n of Air	Speed of Light

3 Department Seminar

As members of the Physics Department community, it is crucial to be active in the events of the community. Without active participation, the camaraderie and strong connections that the department fosters will dissolve. In particular, it is important to participate in the weekly department seminar. Registration in Experimental Physics I carries with it the requirement that you attend the seminar.

Furthermore, you must give at least one of your oral presentations to the seminar, after you have mastered it in the classroom. This presentation should be scheduled with Don Smith at least two weeks in advance and should be completed before Thanksgiving. There is a limit to how many presentations gan be given in a single day's seminar, so do not leave this until the last minute.

It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature.

– Niels Bohr

4 Textbooks

I have asked the bookstore to order *An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements* by John Taylor, University Science Books (1996), ISBN 093570275X. In this class, we will be pushing your understanding of uncertainties, propagation of error, and curve fitting to a higher level than what you encountered in Physics 121/122. We will use this book as a reference, but mostly you will be using it to look up how to carry out statistical analyses rather than as a textbook that we will "work through".

Another book you may want to read is *The Visual Display of Quantitative Information, 2nd edition* by Edward R. Tufte, Publisher: Graphics Press; 2 edition (2001), ISBN-10: 0961392142. There are good graphs, and there are very bad graphs, and Tufte is a master at explaining how best to convey the most information as clearly and as efficiently as possible. You could also consult books such as *Dazzle Em With Style : The Art of Oral Scientific Presentation*, by Robert R. H. Anholt (Publisher: Academic Press; 2 edition (2005), ISBN-10: 0123694523) for information about how to give a good scientific presentation before you begin.

5 Lab Notebooks

One of the most important skills you will develop in actually doing physics is the art of maintaining a good laboratory notebook. A laboratory notebook is more than just a chaotic sketch of bits and pieces of your work. A good lab notebook contains a clear, well-written narrative of your experiment, including drawings of your apparatus, plots of your data (hand-drawn as well as print-outs), the details of your analysis methods, and the results of your statistical tests. A poorly maintained notebook will lead to great frustration when you try to answer questions later on. Trying to ascertain what went wrong, or why your answer is an order of magnitude off, will be almost impossible with a poorly-written notebook. You will not be able to remember dial settings a day after your experiment, let alone three months later.

The ability to maintain a well-written lab notebook is a critical skill for a successful scientist. If your work is challenged by critics, you can defend yourself. If you work in a government lab, or use federal funds to support your work, your lab notebooks are the property of the people of the United States of America, subject to FOIA requests. If you are ever called upon to go back and revisit work you did years ago (which just happened to me recently) your lab notebook may be your only hope of being able to productively reconstruct your work then to be able to build upon it now. In these days of hard drive crashes and lost emails, it is more important than ever to keep a reliable and clear hardcopy of your work.

To help you begin to develop lab notebook skills, you are required to buy a three-ring binder. I will place a template form on the course web page, and hardcopies of the form will be made available in the Advanced Lab room. Each time you work on your experiments, you should take one of these forms and fill it out. This way, over the course of the semester, you will build up a file of notes on your experimental work. We will discuss techniques for maintaining your lab notebook in class.

You are required to meet with me once after each experiment (by Friday of the week of the presentation) to critique your lab notebook. You may do this during our meeting when you watch your video (see section 2.2), but even if you are not the presenter for your experiment, you must still meet with me to go over your lab notebook. Your lab notebook will be graded on a 5 point scale, where a 5 corresponds to clear, complete, and legible, and a 1 corresponds to illegible, scattered, and missing critical information. (You will receive a zero if you do not meet with me.)

6 Grading

Based on the oral presentation, each lab group will receive a grade for the lab. Any presentation may be repeated as many times as desired, and the highest grade received for any of the presentations on a single experiment will be used as the final grade for that experiment. Uncompleted experiments will count as a zero. If more than six experiments are completed, the six highest grades will be used to determine the final grade. A seventh grade will be the median score for your six lab notebook scores. Participation in the department seminar (including but not limited to your presentation) counts as a eighth grade. Finally, a ninth grade consists of a five-point assessment of your participation in class time. Peer critique is an important source

Table 2: Rubric for Grading Experiments

Grade	Experiment	Presentation
A	Understands physical principles Understands equipment Understands meaning and limitations of data Grasps implications of uncertainties	clear concise and complete strong well-organized
B	Poor error analysis Grasp of basic idea okay Adequate understanding of equipment No thought to limitations of result	mildly awkward confusing order lots of ums adequate graphs
C	No error bars Only partial grasp of concepts Barely got equipment to work doesn't understand result	unclear explanations Confusing order Important material missing back to audience
D	Uncertainty omitted entirely Missed the point Equipment didnt work Don't understand what you did	no connection with audience No order to presentation Inaudible Flailing about
F	Didnt do anything No understanding	Inadequate presentation Illegible slides

of assessment and feedback in your learning, and it is at least as important for you to provide feedback for your classmates as they provide feedback for you. Each of these grades is given equal weight towards determining the final grade.

A rubric for grading experiments is presented in Table 2. The descriptions in this table are meant to indicate the sort of properties that typically pertain to the quality of work that receives the given grade, not a firm guarantee (that is, not every talk that contains "lots of ums" will get a 'B'). The final grade for the lab will be the result of balancing all the criteria.

Soon I knew the craft of experimental physics was beyond me. It was the sublime quality of patience – patience in accumulating data, patience with recalcitrant equipment – which I sadly lacked.

– Abdus Salam

7 Course Policies

7.1 Credit Hours

This course is worth two credits, although we will only spend at most three hours in official class contact per week. For a two-credit course, it is expected that you spend on average six hours a week on the course. This expectation is based on the faculty approved standard that students are awarded one credit for every three hours they spend on course work. Roughly speaking, we will likely spend two hours in class giving and critiquing presentations, so expect to spend at least (probably more) four hours a week executing experiments and preparing your presentations.

7.2 Attendance Policy

This class is heavily based in the participation in group analysis of your peers work, both in terms of their execution of the experiment and in terms of their presentation of their results, and therefore chronic absence will interfere with your ability to learn what the class has to offer. Even if you are not presenting, it is crucial that you be there to support your peers efforts and learn from what they did. Guilfords policy for classes that meet once a week is that after three absences, you may be forcibly withdrawn from the course. If you know of an impending situation that will require your absence from class, you must contact me in advance. Tardiness is rude to your classmates and detrimental to the learning environment, and I do not allow it.

7.3 Honor Code

I am a firm believer in acting with integrity and performing at least to the standard of the Guilford Honor code. The work you submit is understood to be claimed by you to be your work. If others helped you, or if you got ideas from other sources, you must credit them appropriately. Images and other materials in oral presentations that were drawn from external

sources must be accompanied by citations that credit the source of hte material. I have a zero-tolerance policy for plagiarism. If I am convinced you have violated the Guilford Honor Code, you will fail this course, and the case will be referred to the Deans office for the possibility of other consequences. According to the college catalog, the statement, "I have been honest and have not observed any dishonesty," gives testament to the honor system and should be pledged in writing on all academic work. Compliance is assumed even if the statement does not appear on college work. The word "pledged" may substitute for the longer statement.

7.4 Accommodations

Guilford complies with the Americans with Disabilities Act by providing a process for disclosing disabilities and arranging for reasonable accommodations. The policy may be found online[1]. Students who require accommodations must complete a disabilities disclosure form and submit it to the Disability Services Coordinator, located in the Learning Commons (x2253), along with the appropriate documentation. It is the students choice to disclose difference/disability informa- tion to individual instructors. However, only students who provide their instructors with a 504 Accommodations Agreement may receive accommodations. All disability information is treated confidentially and is not a part of your academic record.

[1]http://www.guilford.edu/about guilford/values/handbook/ada.html