Physics 312: Advanced Physics Lab

Derin Sherman

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Class is held 9–11 AM and 1–3 PM in West Science Hall Room 005, although the room is available for you to work in pretty much any time of day. West Science Hall Room 009 is also available if you need extra space. There are no formal office hours as I plan to be available from 9 to 5 every day throughout the block, although you are welcome to meet with me at other times since I will often be around the lab even when class is not in session.

Office: West Science Hall Room 021

Office phone: 895-4354

Home phone: 365-1836

E-mail: `dsherman@cornellcollege.edu`

The main purpose of this course is for you to demonstrate your mastery of physics: the ability to design, construct, carry out experiments, and conduct independent research. This course is the most critical part of the physics capstone. Experimental physics is somewhat different than many other sciences insofar as physicists must often build and modify their own equipment to conduct experiments. During this course, you will spend the block researching a single physics topic in depth. Before this course began, you had already met with the course instructor and decided on a course project. During this month, you will design, construct, and conduct your experiment. Depending on the nature of the experiment, you will either work in a small group or individually on your own project. Due to the nature of the individual projects, there is no pre-assigned schedule for each project, although you are expected to attend class on a regular basis: plan on 2 hours in the morning and 2 hours in the afternoon, although there may be exceptions to this policy. You are encouraged to pursue any and all aspects of this project that you find of interest. However, your instructor will work with you to keep you on track to complete your project on time.

Educational Priorities for this course: Inquiry, Reasoning, Communication, Citizenship, Vocation.

You will use your knowledge of physics principles in the research phase of this project to inquire about the principle(s) of physics that are at the heart of your project. Your ability to reason is used to solve the many experimental problems you will encounter in understanding the theoretical basis of your experiments as well as debugging all the experimental problems which will occur as you build and conduct the experiment. You will use your communication skills to explain your project, your experimental results and conclusions in both your final paper as well as your project presentations. Citizenship is also a crucial part of the course: you are expected to help others in the course as well as attending their talks and offering useful critiques and suggestions. Your choice of project should also represent your deeper interest in physics: the final project should be a stepping stone to help you achieve your next goal beyond your Cornell education.

Prerequisites for this course: Electronic Instrumentation (EGR 270), Modern Physics (PHY 265) and one further 300-level physics course. In addition, this course is a capstone experience designed for Senior students. If you are not a Senior student, then you will need special permission from the instructor of this course. In addition, your research topic must be approved by the instructor during the block prior to the course. The course instructor is very willing to help you develop a reasonable research topic. You will not be allowed to participate in the course without a valid research topic.

If you feel you wish to change your research topic or need help selecting a topic, please consult with the course instructor as soon as possible. It is very difficult to change your research topic once the course starts, and virtually impossible to change topic by the second week. Likewise, if you are in need of special equipment, please let the course instructor know as soon as possible.

During the course, you will conduct three presentations of your work, write a paper describing your work, and submit a journal with your daily observations. The presentations will be held on the 2nd, 3rd, and 4th Mondays of the course. These presentations will be in-class only, although other physics professors may be present and ask questions. During the first presentation you should present an overview of your project. You should explain what your project is and why it is important. You should give enough theoretical background so that people can understand the relevant physics of the project. You should also outline your project goals: what do you expect to have accomplished by the end of the block? If you have some preliminary data (or demonstration of a work in progress) please feel free to present this as well. Be prepared to answer any reasonable questions that the instructor (or other lab members) may have.

The second presentation is more of a progress report designed to update the lab members as to the current status of the project. You should have some preliminary data to present to the group. You may want to assess your initial goals and set more realistic goals for the end of the block.

The third presentation is meant as a practice presentation for the public presentations you will give after the class is over. As such, your third presentation should be geared to a scientifically literate audience, but not one that is familiar with the work that you've been conducting. You will have to explain your work in more general terms and leave highly technical matters to the end of your talk. Your talk should be about a half-hour long, but it could be longer if your project involves many details. For example, if you had to build a very complicated piece of apparatus, your talk might run as long as an hour.

In addition, it is expected that you will give one or two more presentations of your work: a presentation during the Physics and Engineering pizza lunch and possibly a presentation at the Student Symposium. The typical Student Symposium presentation is a Poster presentation, and the Physics and Engineering pizza lunch presentation is an extended version of your third presentation: this will permit you the time to go into the details that you will, inevitably, have to omit from your 4th week presentation due to time restrictions.

The paper is a technical version of your final presentation and is due at the end of the course. The paper should include both a general explanation of the experiment (background to the experiment, general physics knowledge relevant for your experiment, what you did, why it was important) together with an explanation of the specific work done by you that is sufficiently detailed for another experimentalist to pick up where you left off. This is important: think about the information you wished you had at the start of your experiment that would have made the experiment easier to do. This crucial information belongs in your paper.

Your paper should tell a story: it should explain to people why your experiment is interesting. The paper should not be a mere list of facts: "First I did this, then I did this, ..." You should probably begin your paper by choosing an important question related to your project. This question should be of interest to you: it might not be the question that other members in your group find interesting. Note that your question will probably change throughout the block. For example, you might start with a very general question, such as, "How can we make holograms using sound instead of light?" and then evolve as you refine your experiment.

By the end of the second week, you will submit a rough draft of your paper. While most of you will not have collected definitive data by the end of the second week, you all should have fairly well-defined research questions and a very good understanding of the equipment and experimental techniques required to conduct your experiment. Your rough draft should describe the research question you're trying to answer as well as providing experimental background and motivation for your experiment. Your rough draft will probably not include experimental findings and conclusions as you will still be in the process of collecting data.

Your instructor will provide you will feedback on both your rough draft and your final presentation. You should use this feedback to help you revise your paper. The revision process often involves re-thinking the entire paper. Your rough draft is often a guide to what you want to say in your final paper, but it may also be a guide to what you don't want to say. Very often, the final paper may bear little relation to the rough draft.

You will also keep a daily journal of your work, which will be submitted to the instructor at the end of the course. This journal may be kept in a lab notebook, a regular notebook, or in electronic format e.g. a Word document on a flash drive. The purpose of the journal is to record your data, thoughts, and observations as you conduct your experiment. These observations are often very helpful when it comes time to write your final paper, and they are also useful for other scientists who are trying to reproduce your results. At the very least, you should record at least one paragraph per day describing the important events of the day and what you discovered. Most likely, you will record your data and observations for that day, as well as any thoughts you might have regarding your research.

Illness in this course is usually not of concern: missing a couple of days should not interfere significantly with a project that takes several weeks. However, should your illness be prolonged (a week or more) then you may have to consider either dropping the course or receiving a grade of incomplete and finishing the course work later in the year. In either of these cases, you should consult with your instructor.

Your grade is based on the following factors:

- Productivity: how well did the experiment work? Did you meet your goals?
- Presentations: how well did you communicate your work?
- Teamwork: how well did you work with other lab members? This includes people outside your own group.
- Effort: how hard did you work?
- Efficiency: how much progress did you make?
- Education: how much did you learn while doing the experiment?
- Initiative: how well did you solve problems on your own?
- Revision: how effectively did you revise your paper during the block?
- Documentation: how well did you document your research in your journal?
- Attendance: how regularly did you attend class?

Academic Integrity: Unless otherwise stated, assignments are for you to complete on your own. In some cases, they will be based on group work done in class. In these cases, please provide proper attribution to other's ideas. Failure to properly reference other people's ideas may result in a failing grade. Cornell College expects all members of the Cornell community to act with academic integrity. An important aspect of academic integrity is respecting the work of others. A student is expected to explicitly acknowledge ideas, claims, observations, or data of others, unless generally known. When a piece of work is submitted for credit, a student is asserting that the submission is her or his work unless there is a citation of a specific source. If there is no appropriate acknowledgement of sources, whether intended or not, this may constitute a violation of the College's requirement for honesty in academic work and may be treated as a case of academic dishonesty. The procedures regarding how the College deals with cases of academic dishonesty appear in The Catalogue, under the heading "Academic Honesty."

When writing papers, you must provide citations for any material that is not your own work. If you have any questions about citation, please consult either your instructor, or a member of the library staff. It is not permitted to copy from another student's lab notebook unless you are doing the lab with that student. If you get stuck on part of a lab, you should feel free to consult with other students, but you should acknowledge any help you receive from those students. For example, "We initially didn't see any signal, but the signal was clearly visible after Christiane and Stanley suggested that we increase the slit size from 0.1 mm to 1.0 mm."

It is often unclear when you must cite an equation. In general, all equations must be cited, but there are a few exceptions. If the equation is common knowledge, it need not be cited. For example, you need not cite Isaac

Newton when you use the equation $F = ma$. You may assume that any equations that appear in introductory physics texts that you have used in previous physics courses, are fairly common knowledge, although you may want to cite equations from your more advanced physics texts. Also, you need not cite an equation if you can derive it from first principles and include the derivation in your paper (possibly as an appendix).

It is very important to maintain accurate records of the data you collect. Destruction of data is usually forbidden as it could mean disregarding facts that contradict a theory under test. As a general rule, all data must be preserved and analyzed. However, there are some instances when it is permissible to disregard data. If data are collected using faulty apparatus (often a malfunctioning sensor) such that the data amount to no more than a record of noise, then a notation is made in the lab notebook of the faulty sensor and the data may be disregarded.

Data may also be selectively analyzed if data collection takes place outside the realm of the experiment. For example, consider an experiment designed to measure the acceleration of gravity by measuring the position of an object falling toward the floor. At time t = 0.0 s, the computer starts to record data. At time t = 2.0 s the object is dropped, and at t = 2.2 s the object hits the ground. At time t = 4.0 s the computer stops recording data. The computer has recorded the position of the object for a total of four seconds, yet only two-tenths of a second need to be analyzed: the data corresponding to the time when the object was falling. Although the complete four second set of data should be saved, the time during which the object was falling should be recorded, and only the interval from 2.0 s to 2.2 s should be analyzed.

A more serious problem is data fabrication. Data may be fabricated in many different ways. An extreme form of data fabrication is “reverse engineering” the data. For example, if your experiment asks you to determine the acceleration of gravity by timing the fall of an object over a distance of one meter, then using the formula

$$d = \tfrac{1}{2}gt^2$$

to find g, you should not use this formula and the textbook acceleration of gravity (9.8 m/s^2) to work backwards to determine the time to fall. You might want to compute this theoretical value and compare it to your experimental values, but you should never report the theoretical value as though it were a measured value.

One of the more subtle means of fabrication is data duplication: claiming to have repeated an experiment when you have merely replicated an earlier run of data. For example, if you have collected two sets of data and your instructor asks you to collect a third set of data. It would be academically dishonest to construct a third set of data by averaging the values of the two previous sets of data and then claiming that the averages constituted a new set of measured values.

A third problem is failing to record vital parts of your procedure. When you write the procedure part of your lab notebook and paper, your goal should be to include enough detail to let others accurately reproduce your work. Although you are not required to reproduce every detail of the procedure from the lab handout, your paper should describe the essential details. You must describe any departure from the lab handout procedure. Problems could range from minor (forgetting to describe an important part of the procedure) to major (deliberately lying about the procedure). Minor infractions will result in a reduction of your grade. Major infractions will result in a failing grade.

Any student found cheating on a paper will receive a zero for the course. The Registrar will also be notified.

The following guide is used to determine your grade.

Grade of A:

Students receiving an A have clear, concise, well-rehearsed presentations containing many new ideas. These students are able to answer most questions put to them.

Their papers show an advanced understanding of the subject material; describe the experiment clearly and concisely; tell compelling stories, and are enjoyable to read. These papers are able to connect their experiment to other work (either historical or current) and show how their project fits in to “the big picture.” Not only is the experiment described in sufficient detail for another group to continue work on the experiment but the paper is of sufficient quality to consider formal academic publication. These students have been able to solve most (if not all) of their experimental problems on their own and often help other groups solve their problems as well. Their mastery of their research topic exceeds that of the course instructor.

Grade of B:

The presentations of students receiving a B are clear and concise, but may not be well-rehearsed, and they may not be able to answer all questions.

Their papers describe the experiment clearly and concisely, but they either don't have an advanced understanding of the subject material or they don't tell a compelling story. The experiment is described in sufficient detail for another group to continue work on the experiment. These students have been able to solve many of their experimental problems on their own.

Grade of C:

The presentations of students receiving a C are competent, but may not be well-rehearsed, and they are usually not able to answer all questions.

Their papers describe the essential details of the experiment but lack a deeper understanding of the material. These students are often not able to solve experimental problems on their own. The paper should contain most of the information needed for another group to continue work on the experiment.

Grade of D:

Students receiving a D have poor presentations and they are usually not able to answer questions.

Their papers are often missing key experimental details, and they have often not been able to complete the experiment.

Grades of A and D are rare in this course. Most students will receive grades of B and C.

Capstone: The project you pursue in this course constitutes your capstone experience and the final paper represents the culmination of the capstone experience. At the end of the course, you will submit your paper for review. In the unlikely event that your capstone paper is found to be unacceptable, you will revise it until it is accepted by the physics department. Once it has been accepted, you will then present the capstone paper in a public presentation, such as the Student Symposium. If the presentation is judged unacceptable, you will be given the opportunity to re-present the paper privately to the department.

Safety: If you are not familiar with the operation of a particular piece of equipment, please consult your instructor. The power tools are capable of injuring you or your lab mates if not used properly. Also, expensive equipment may be damaged if not used properly.

Students with disabilities: Cornell College makes reasonable accommodations for persons with disabilities. Students should notify the Coordinator of Academic Support and Advising and their course instructor of any disability related accommodations within the first three days of the term for which the accommodations are required, due to the fast pace of the block format. For more information on the documentation required to establish the need for accommodations and the process of requesting the accommodations, see http://www.cornellcollege.edu/academic-support-and-advising/disabilities/index.shtml