West Chester University

Department of Physics

Physics 310 – Intermediate Lab I

Meeting Times: W 3:00 - 5:45 pm

Meeting Place: Merion Science Center 109

Instructor: Jeffrey J. Sudol (Dr. Jeff)

Office: Merion Science Center 130

Office Phone: 610-436-2572

Office email: jsudol@wcupa.edu

Office Hours: MWF 12-1, M 3-4, T 1-2

Course Description

During the Physics 310-320 sequence, you will conduct several of the classic experiments from the 19th and 20th centuries designed to measure the fundamental constants of nature, such as the universal gravitational constant (*G*), the speed of light (*c*), the charge of the electron (*e*), and Planck's constant (*h*). These experiments lie at the heart of modern physics, and the structure of the Universe depends critically on the values of these constants.

Required Course Materials

- ✓ *An Introduction to Error Analysis*, 2nd edition, Taylor.
- ✓ A laboratory notebook.
- ✓ A scientific calculator.

Attendance Policy

Attendance is required.

Website

This course has a D2L website associated with it. I will post all course documents and announcements on the D2L website. Please check D2L frequently.

Course Goals

Physics 310 is an approved Writing Emphasis course in the WCU General Education program. The writing sessions, laboratory practices and data analysis sessions, draft review meetings, and presentation sessions that take place during the semester, as well as the feedback that the faculty give you on your papers and presentations, are all designed to help you meet the following General Education goals: (1) students will be able to communicate effectively, (2) students will be able to employ quantitative concepts and mathematical methods, and (3) students will be able to think critically and analytically.

In discipline-specific terms, this course is designed to meet the following goals.

1. The student will become proficient at using a wide range of experimental tools and measurement techniques common in the modern physics research laboratory.

2. The student will become proficient at estimating and calculating uncertainties.

3. The student will become proficient at communicating the design of an experiment and the results of that experiment to an audience of physicists in writing through research-style papers and in person through research-style talks.

The Experiments

During the semester, you must conduct four experiments and document those experiments in a laboratory notebook. You must write and submit "research papers" on three of those experiments and prepare a "research presentation" on the fourth. We will discuss the selection process for those experiments during our first class.

The Department of Physics has purchased the equipment required to perform the experiments listed below. (The PHY 320 list is provided for context.)

<u>PHY 310</u>

Planck's Constant (The Photoelectric Effect)
The Half-life of a Radionuclide[1]
The Wavelength of a Laser Diode
The Charge-to-Mass Ratio of the Electron
The Quantization of Atomic Energy States (The Franck-Hertz Experiment)
Avagadro's Number
The Speed of Light (distance-velocity-time method)
The Fundamental Unit of Electric Charge (The Millikan Oil Drop Experiment)[2]
The Universal Gravitational Constant (The Cavendish Experiment)[2]

[1]This experiment requires training in the safe handling of radioactive materials.
[2]These experiments may only be done for presentation (no papers).

PHY 320

The Fundamental Unit of Electric Charge (The Millikan Oil Drop Experiment)
The Universal Gravitational Constant (The Cavendish Experiment)
The Speed of Light (Foucault's Method)
The Speed of Light (Ole Roemer's Method)[1]
Electron Spin Resonance
The Hall Effect
The Zeeman Effect
Nuclear Spectroscopy of Materials[2]
The Index of Refraction of Air[3]
The Sodium Doublet
The Mass of the Neutron

[1]This experiment requires training in the use of a telescope to time the eclipses of Io.
[2]This experiment requires as a pre-requisite successful completion of the half-life experiment.
[3]This experiment requires use of an excel spreadsheet maintained by Dr. Sudol.

The Laboratory Notebook

You will maintain a laboratory notebook during this course as you did in PHY 170 and 180. Your laboratory notebook will serve as the foundation on which your formal reports and presentations are built. I am operating under the assumption that you know how to document an experiment in a laboratory notebook from previous course work. If you are not confident in your skills in this area, please discuss the matter with me as soon as possible.

Laboratory Practices and Data Analysis

I will conduct three "laboratory practices and data analysis sessions" during the semester (see the **Course Schedule** below).

The PHY 310 laboratory experience differs from your PHY 170 and PHY 180 laboratory experiences in the following ways.

You are on your own recognizance to conduct experiments in the laboratory space dedicated to this course (MER 114 and MER 116). In other words, you set your own schedule, except with regard to the deadlines for papers and presentations.

You are on your own to assemble the apparatus to conduct an experiment.

You must develop your own procedures for conducting an experiment and analyzing the data. Although such procedures are often provided in equipment manuals, those procedures are often flawed or designed for instructional purposes. Your must develop

procedures appropriate for a research laboratory environment, not an instructional laboratory environment.

You must make arrangements with the other students in the class with regard to the use of the equipment and the laboratory space so that no conflicts occur. You must keep the laboratory space in good working order at all times.

You must avoid creating safety hazards. If, at any time, I find a safety hazard, I will take into possession all of the equipment associated with that hazard, thus disrupting your experiment. I will release the equipment after we meet to discuss the nature of the hazard and how to avoid it in the future.

This arrangement is designed to encourage you to engage in professional conduct. In general, in the sciences, laboratory facilities and laboratory equipment are shared due to their high cost. Consequently, coordination, cooperation, and consideration are critical to everyone's success.

In the interest of lab safety, you must work with at least one other student on all experiments. In the interest of equal participation, however, you may not work in groups of more than three students.

Finally, take note that all of the experiments "work". That is, when all of the equipment is calibrated and when the experiment is executed properly, the experiment produces a result that is consistent with results published in the professional literature. If the value that you obtain for a fundamental constant is not in agreement with (or consistent with) values published in the professional literature, you must take the following actions to discover what error has occurred and fix it. (1) Where possible, calibrate the equipment and make sure it is working properly (which you should have done before doing the experiment). (2) Check the equipment for defects and damage (which you should have done before doing the experiment). (3) Consult a faculty member regarding the procedure or the data analysis. (4) Ask me to check the equipment. **Do not disassemble or attempt to repair equipment.** Leave that to me. A paper or presentation in which the result is not in agreement with the literature will not receive a particular high score. Troubleshooting may take many hours, so it behooves you to plan far ahead and take good notes.

Bear in mind that professional scientists have no reference values against which to compare their results, but they do have extensive experience conducting experiments, and they execute their experiments with great care. In this class, you will be acquiring the kind of experience that allows you to execute experiments with great care, and one component of that experience involves comparing the results of your experiments to well established values in the literature. Because you know "the answer", you might be tempted to commit all kinds of terrible crimes against the data. You must be extremely careful not to introduce any bias in your work because you know the answer. Stay honest. I'm here to help when you get stuck.

Caring for Equipment

The equipment that you will use to conduct experiments during this course is quite expensive. The total cost for all of the equipment in the lab exceeds $250,000. Single items can be quite expensive, too. For example, the Fabry-Perot etalon costs $3,500, and the x-ray diffractometer costs $22,000.

Food and Drink are expressly prohibited in MER 114 and MER 116.

Upon the first offense, your access privileges to MER 114 and 116 will be revoked, and you must see me to gain access to the lab each time you want to enter the lab.

Upon the second offense, you fail this course.

Despite the high cost of the equipment, caring for the equipment requires no special training. Simply put, plan ahead. All of the manuals for the equipment in the lab are available on D2L, and all of the manuals describe how to handle the equipment safely. I expect you to read the manual for each piece of equipment from cover to cover before using the equipment. (The colloquial notion that "nobody reads the manual" is a myth. Read the manual!) Familiarize yourself with the equipment before using it. Create a "script" of all of the actions that you are going to execute during an experiment before you execute them. Review that script. Think about all of the ways you might harm the equipment before you take any action. When you are confident that your actions will not harm the equipment, then proceed with the script.

Equipment Release-Return Program

To hold you accountable for taking good care of the equipment, the following policies are in effect.

1. All of the equipment cabinets in the labs are locked. A complete inventory of the equipment is available on D2L. You will automatically receive a failing grade for the course if I find that you have tampered with any of the locks. You may also be evicted from the Physics program after an inquiry into the nature of the crime. (See the Physics Student Handbook.)

2. I will be available during my office hours to release equipment and take equipment in return.

3. You must submit an "Equipment Request" to me when you arrive to take possession of equipment. The Equipment Request form is available on D2L. If someone else has submitted a request for the same equipment ahead of you, or if someone else is in possession of the equipment, I will not be able to release the equipment to you. You must communicate your equipment needs to your fellow students so that no conflicts occur (see **Laboratory Practices** above). **Please pay careful attention to the tag numbers on the equipment.** For example, we have several multi-meters. Each has a different tag number. Do not default to requesting multi-meter #1 each time you make a request. Determine which multi-meters are actually in use and choose one accordingly.

4. You may not take possession of more equipment than is required to run one experiment at a time.

5. You will automatically receive a failing grade for the course if I find that you are using equipment that (1) has not been released to you, (2) is not part of the equipment inventory, or (3) has not been sanctioned for use in the lab by me.

6. Equipment transfers between groups are not allowed. (The experience of calibrating equipment and assembling an apparatus in order to conduct an experiment is critical to your future success in physics.)

7. You may not join a group to which equipment has already been released. (Your name must appear on the equipment release form for all of the equipment you are using. See #5.)

8. You have three hours after receiving any piece of equipment to check that equipment for damage and report any problems. (See item #10 below.)

9. You may not hold equipment for more than three weeks. At the end of three weeks, I will return the equipment to inventory, and I will not release that equipment to you again.

10. Penalties for damaged equipment are assessed as follows.

    Whenever a piece of equipment is damaged, I will charge all students in the course a "$100 penalty." (I am not actually charging you $100. You do not have to pay to replace broken equipment. This is an "accounting mechanism" for grade penalties, which is described further below.) This charge takes into account the possibility that prior students have abused the equipment in some way, making it susceptible to failure.

    I will charge the individual who damaged the equipment the full cost to repair or replace the equipment. If an entire group is responsible for the damage, I will divide the cost to repair or replace the equipment amongst the group.

The group in possession of the damaged equipment must complete a repair order or a replacement part order to my satisfaction before the group may take possession of any additional equipment. (Equipment Repair and Equipment Replacement forms are available on D2L.)

11. If you receive equipment that is damaged, I will begin an investigation into the cause of that damage and assess penalties as I see fit. Appeals may be made to Dr. Nicastro, who will serve as arbitrator.

    Penalties are doubled for equipment that is returned damaged without notification.

12. Penalties for damaged equipment translate into grade penalties. After assigning a grade to a paper or presentation, I will deduct a partial letter grade for each increment of $500 in penalties accrued since the previous paper or presentation. Any remainder carries over to the next graded item. For example, if you receive a B+ on a paper, and you have accrued $800 in penalties, your grade drops to a B, and the remainder, $300, carries over to the next graded item.

Research Papers

I am the audience for your paper. You are not writing the paper to be published in a scientific journal, although your paper should have the look and feel of a professional paper (as described below). You are not writing the paper for physics majors or humanities majors or professional scientists. You are writing the paper for me, the person who is to judge the quality of your work. That being said, know that my judgment is well aligned with that of the scientific community. I have also made a concerted effort to articulate the qualities of a good paper in the grading rubric posted on D2L. By way of summary, the mark of a good, scientific paper is transparency. The mark of a good experiment is reproducibility, and a good scientific paper is sufficiently transparent to allow the reader to reproduce the experiment and its result. Furthermore, in a good, scientific paper, the author builds credibility with the reader. The fundamental goal of this course is to provide you with the experience that allows you to arrive at an understanding of what it means to be transparent, what allows another reader to reproduce your work, and how to build credibility.

Although you are not writing the paper to be published in a scientific journal, the research papers that you submit must conform to the standards and conventions described in the *American Institute of Physics Style Manual*. The standards and conventions of a discipline are not arbitrary but allow for the efficient communication of information. I have posted an abridged version of this manual on D2L. (Some parts of the manual, such as "Correspondence before acceptance", are not pertinent to our particular situation.) The point here is to put you in the same situation as the professional scientist, who must write for a particular audience and reach them through a specific medium, which requires some modicum of standards and conventions.

To help you build an understanding of transparency, reproducibility, credibility, and the standards and conventions of the physics community, I will hold several "writing sessions" during which we will review, discuss, and make revisions to writing samples (see the **Course Schedule** below).

Draft Review

I will meet with each of you, individually, for 45 minutes to comment on your first two papers before you submit them for a grade. Please bring two copies of your paper to these draft review meetings, one for me to read and one for you on which to take notes.

Unfortunately, the phrase "draft review" is a bit misleading. Don't be misled. During draft review you must submit what you intend to be the final draft of the paper. I will not review a draft that is incomplete or does not represent an authentic attempt to be complete. Failure to present a complete draft will also result in the loss of credit on the final draft of the paper.

Final Draft

The final draft of each paper is due one week after we meet for draft review. I will commit as much time as is reasonable to make comments on your final draft in order to help you improve your writing. My expectations for the quality of your work will increase as the semester progresses, so you must take my comments into consideration before writing the next paper.

Research Presentations

Toward the end of the semester, you will give a talk describing one of your experiments and its result to an audience of your peers and professional scientists, notably, the faculty in the Department of Physics. The experiment on which you give the talk must be different from one of the three for which you wrote a paper. Your talk is limited to 15 minutes in a 20 minute time slot, leaving 5 minutes for questions. Members of the audience may interrupt you at any time during the presentation to ask questions. The faculty and I will provide written feedback on your presentation afterwards.

With regard to the research presentations, I am not your audience, but you will be well served to think of me as your audience. My expectations generally reflect those of the department as well as the scientific community at large.

I will hold one "presentation session" during which I will give a research presentation and afterwards we will discuss its salient features (see the **Course Schedule** below).

Assessment

Your "grade" in this course will be based on your performance in the following categories of assessment with the following weights.

(3) Research Papers ..... 25% each
(1) Research Presentation 25%

I will assign each paper and the presentation a letter grade of A, B, C, D, or F, based on my professional judgment, articulated in the grading rubrics posted on D2L.

I reserve the right to introduce different forms of assessment as needed and to alter the weight of each of the categories of assessment in the event of some unforeseen circumstance.

Although I am the person who assigns a grade to your work, keep in mind that, during the research presentations, other faculty in the department will evaluate your work and submit their evaluations to me for consideration.

Misconceptions

1. Most students harbor the misconception that reading and writing are independent of one another. This misconception arises from two general truths (i) reading is a "passive" activity while writing is "active" and (ii) practice makes perfect. So, it might not make sense at first that "practicing" reading makes you a better writer, but reading and writing correlate quite well with one another. The best authors tend to be the most voracious readers. While reading text within a discipline, you learn how words relate to one another, their juxtaposition and relative meaning, the context in which those words are used, and the structure of a language within a discipline.

2. Most students harbor the misconception that writing is a universal skill. The truth is that poetry, short stories, novels, technical manuals, legal documents, and scientific research papers, to name a few, require different skill sets. Grammar is universal; "writing" is not. Keep in mind that short stories and novels represent "narrative," whereas scientific journal articles represent "exposition." These two modes of writing are quite different from one another.

3. Most students harbor the misconception that scientists spend most of their time "doing science" in a lab. This is far from the truth. Scientists spend most of their time preparing to conduct an experiment, documenting the experiment while it is in progress, analyzing the data from the experiment, and communicating the results of the experiment to the scientific community. Nearly all of this work is "bookish," requiring a lot of reading and writing. Most of the experiments that you will conduct in this course require no more than 30 minutes of active attention to the experiment to collect data; some, as little as 10 minutes. Yet, the complete cycle, from the time

you decide to do a particular experiment to the time you submit the final paper reporting on the experiment, will require 20 hours on average.

Email Policy

Per the Undergraduate Catalog, you are required to activate and maintain the email account created for you by West Chester University. I will not use any other email account to communicate with you. I do not have internet access from home. I do not forward my email to my phone. This means that a day or two might pass before I respond to any messages that you send to me. Plan ahead.

Disability Statement

If you require special accommodations because of a disability, please meet with me as soon as possible to discuss your needs. Supporting documentation from the Office of Services for Students with Disabilities (OSSD) is required. For more information regarding this policy, click here: Undergraduate Catalog: Services for Students with Disabilities.

Policy Regarding Grade Assignments

Grade assignments are final and cannot be changed once submitted at the end of the semester, unless a clerical or computational error is discovered. "No Grade" assignments are made only under extraordinary circumstances. Credit by Examination is not available for this course. For more information, click here: Undergraduate Catalog: Grade Changes.

Academic Integrity Statement

If you commit a violation of academic integrity, you will receive zero credit for the entire course. This is not negotiable. For more information regarding violations of academic integrity, click here: Undergraduate Catalog: Academic Integrity Policy.

Student Code of Conduct

I will dismiss students from class for any violation of the Student Code of Conduct and initiate the disciplinary action appropriate to the violation. For more information regarding violations of the student code of conduct, click here: Student Code of Conduct.

University Sanctioned Events

If you will be participating in a University sanctioned event that occurs at the same time as a research presentation, you must notify me one week prior to the presentation. Documentation supporting your participation in this event is required. For more information on University Sanctioned Events, click here: Undergraduate Catalog: University Sanctioned Events.

Intellectual Property Statement

All of the course materials are the intellectual property of the instructor or another author. Your use of these materials is restricted to your own studies for the duration of this course. It is a violation of Federal Law for you to distribute copies of these materials to anyone in any format at any time.

Electronic Equipment in the Classroom (Unplug)

Except for calculators, I do not permit the use of cell phones, cameras, voice recorders, computers, or similar electronic equipment in the classroom unless you need to use such a device to accommodate for a disability, in which case you should schedule a meeting with me to discuss the proper use of the device and the data obtained with that device as soon as possible. The spirit of the rule is that the classroom should be an electronic free zone where we tune out the distractions of the world and focus on learning physics. The classroom is a place of dialogue, and the electronic gadgets of our modern culture are not necessary for that dialogue to take place.

Course Schedule

Note: We will set meeting times for draft review during the first class session.

Date	Lecture Activities
Jan. 25	Introduction
Feb. 01	Laboratory Practices and Data Analysis Session #1: The Measure of Uncertainty
Feb. 08	Writing Session #1 - Sample Paper
Feb. 15	Laboratory Practices and Data Analysis Session #2: Chauvenet's Criterion, The Central Limit Theorem
Feb. 22	Writing Session #2 - Theory
Mar. 01	Writing Session #3 - Apparatus
Mar. 08	Writing Session #4 - Procedure & Data
Mar. 15	*No Class - Spring Break*
Mar. 22	Laboratory Practices and Data Analysis Session #3: Peak Finding, Modeling Data (linear regression)
Mar. 29	Example Presentation
Apr. 05	*No Class*
Arp. 12	Student Presentations
Apr. 19	Student Presentations
Apr. 26	Student Presentations
May 03	Final Paper Due