West Chester University

Department of Physics

Physics 310 – Intermediate Lab I

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

Meeting Place: Merion Science Center 116

Instructor: Jeffrey J. Sudol (Dr. Jeff)

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Office Hours: M1-3, W1-2, F1-3

Course Description

During this course, you will conduct several of the classic experiments from the 19th and 20th centuries designed to measure the fundamental constants of nature. Let that sink in for a moment: You will measure the fundamental constants of nature, such as the Universal Gravitational Constant, the speed of light, the charge of the electron, and Planck's constant. These experiments lie at the heart of modern physics, and the very 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" from the BookFactory (soft cover, blue, 162 pages, quadrille ruled paper).
- ✓ A scientific calculator.

Attendance Policy

Attendance is required.

Website

This course has a D2L website associated with it. I will post all of the course documents and announcements on the D2L website on a regular basis. Please check D2L every day for updates.

Course Goals

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

2. The student will advance his or her ability to work independently to conduct experiments in a laboratory environment.

3. The student will become adept at using a wide range of statistical tools to estimate or determine the uncertainties in measurements and to determine the uncertainty in the end result of an experiment.

4. The student will advance his or her ability to communicate the design of an experiment and the results of that experiment to an audience of physicists in writing through formal research papers and in person through research talks.

The Experiments

The Department has purchased the equipment required to perform the experiments listed below. You must choose five of these experiments to complete during the semester.

PHY 310

The Speed of Light
The Charge to Mass Ratio of the Electron
The Measurement of the Wavelength of Laser Light (Michelson Interferometry)
The Fundamental Unit of Electric Charge (The Millikan Experiment)
Planck's Constant
Magnetic Permeability (Current Balance)
Interatomic Distances (X-ray Diffraction)
Thermal Radiation and the Stefan-Boltzmann Law
The Gravitational Constant
Avagadro's Number
The Franck-Hertz Experiment
The Boltzmann Constant
The Half-Life of a Radionuclide[1]
The Index of Refraction of Air[2]

[1]This experiment requires training in the safe handling of radioactive materials.
[2]This experiment requires an excel spreadsheet maintained by Dr. Sudol.

PHY 320

Electron Spin Resonance and the *g* Factor
Nuclear Magnetic Resonance Spectra
The Hall Effect
The Zeeman Effect
Nuclear Spectroscopy of Materials[1]

[1]This experiment requires training in the safe handling of radioactive materials.

The Laboratory Notebook

You will maintain a laboratory notebook during this course. 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 uncertain about your abilities to document an experiment, please discuss the matter with me as soon as possible.

Course Schedule

Over the course of the semester, your task is to preform five experiments, write and submit formal reports for three of those experiments, and prepare and present one research talk on one of the two remaining experiments not documented in the formal reports. To keep everyone on task and maintain some measure of order in the laboratory, I have created the following schedule showing the benchmarks that you must reach as the semester progresses. An explanation of each benchmark follows the schedule.

Date	Lecture Activities	Benchmarks	
Aug. 28	The Measure of Uncertainty The Design of an Experiment		
Sep. 04	Rejection of Data	Submit procedure for Experiment #1	
Sep. 11	Weighted Averages	Submit procedure for Experiment #2	Experiment #1 completed
Sep. 18	Error Bars Fitting Equations to Data	Submit procedure for Experiment #3	Experiment #2 completed
Sep. 25	The χ^2 Test	Submit procedure for Experiment #4	Experiment #3 completed
Oct. 02	Journal Papers	Submit procedure for Experiment #5	Experiment #4 completed
Oct. 09	Papers: The Good, The Bad, and The Ugly	Submit Draft of Research Paper #1	Experiment #5 completed
Oct. 16	Research Talks	Submit Research Paper #1	
Oct. 23	Papers: The Good, The Bad, and The Ugly	Submit Draft of Research Paper #2	
Oct. 30		Submit Research Paper #2	
Nov. 06	Presentations		
Nov. 13	Presentations		
Nov. 20	Presentations		
Nov. 27	*No Class*		
Dec. 04		Submit Research Paper #3	

Submitting Procedures

I am requiring you to submit a "procedure" for each of the lab experiments that you choose to complete for the following reasons. Professional scientists do a lot of planning *before* executing an experiment. Good science is fantastically dull in that well-designed and executed experiments are often unremarkable. The data analysis is, in fact, the exciting part, when the final result emerges from the data. Professional scientists often submit proposals to use laboratory equipment that is far too expensive to purchase for their own labs. These are known as "community resources." For example, astronomers purchase time on telescopes to conduct observations, and physicists purchase time on particle accelerators to conduct experiments. The competition for these limited and valuable resources is fierce. The "time allocation committees" who oversee these resources allow only those scientists who write convincing proposals to use the resources. So, the requirement that you submit a procedure for each experiment is your introduction to the process through which scientists submit proposals to use laboratory equipment to conduct experiments. I don't expect you to write professional proposals at this stage in your career, of course. Fundamentally, all you are required to do is to answer the following questions.

- What do you want to know?
- What are you going to measure?
- What equipment are you going to use to make those measurements?
- How are you going to get from what you measure to what you want to know?

You may not conduct an experiment until I have cleared you to do so. If I find significant faults with your procedures, I will ask you to reconsider and resubmit them. As time goes on, I expect your procedures to improve. While working on the procedures for an experiment, you should inspect the equipment to be used in that experiment to get a feel for how each piece of equipment works. You should consult the manuals associated with that equipment (but be skeptical). You should consult descriptions of the experiment in books and on the internet (but, again, be skeptical). You should work out the theory underlying the design of the experiment, too.

Conducting the experiment

When I clear you to conduct an experiment, I will designate a space in MER 116, MER 118, or elsewhere in the department where you will conduct the experiment. You will have until the beginning of the next lecture period (Wednesday at 3:00 pm) to complete the experiment, pack up the equipment, and place the equipment in storage. I expect all laboratory space to be clean at the start of every lecture period.

Please report broken or missing equipment immediately to both me and Dr. Sawyer (wsawyer@wcupa.edu). Equipment will break. You should always think ahead and do your best to prevent damage to the equipment, but accidents do occasionally happen and things do fall apart. If you broke something, be honest about it. In fact, record what happened. How did it break? We will all learn from the experience. Moreover, other students need to conduct these experiments, so we need to replace the equipment promptly so that everyone in the class can conduct the experiments successfully.

If you find you are pinched for time, do not rush to complete an experiment. Haste makes waste. It is better that you fail to complete the experiment, and we make a plan for you to complete the experiment later in the semester than something should go wrong.

Submitting Draft Reviews

For the first two research papers, I will accept drafts for review. I will not accept drafts after 3:00 pm on the date indicated in the **Course Schedule**. Although I use the word draft, I expect a complete paper ready for submission for a grade (see **Research Papers** below). I will spend no more than 30 minutes commenting on the draft. If the draft is in bad shape, this will leave you with an incomplete review, so it behooves you to prepare a good draft.

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 15%, 25%, 35%
(1) Research Presentation 25%

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.

Note that I am not the sole judge of your performance. During the research presentations, other faculty in the department will evaluate your work and submit their evaluations to me for consideration.

Research Papers

The research papers that you submit must conform to the standards of the publications in physics and astronomy. I will provide several examples in class, but I recommend following either the instructions for authors for *The Astrophysical Journal*, found at the following URL,

http://aas.org/authors/manuscript-preparation-aj-apj-author-instructions,

or the instructions for authors for *The Physical Review*, found at the following URL,

http://pra.aps.org/info/infoA.html.

The latter URL references *The Physical Review Style and Notation Guide*, found at the following URL,

https://publish.aps.org/files/styleguide-pr.pdf.

The notable exception to these guidelines is that you are not preparing a paper to be typeset to be published in a journal. Professional journals ask for each table and figure to appear on a separate page, or, in some cases, to be submitted as separate files, so that the tables and figures can be typeset into the journal. You are not publishing in a journal, so, instead, embed your tables and figures into your research paper rather than placing them on separate pages. In other words, you should prepare a paper that has the look and feel of the "final product" that would appear in a journal.

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 of 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 might interrupt you at any time during the presentation to ask questions.

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 is required.

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, consult the Undergraduate Catalog.

Intellectual Property

All of the course materials are either my intellectual property or the intellectual property of 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)

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 use of the 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.