Physics 320 – Intermediate Lab II Spring 2018

Meeting Times: T 3:20 - 6:00 pm

Meeting Place: SSN 191

Instructor: Anthony J. Nicastro

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Office Hours: MW: 10 a.m. – 11 a.m.; 1:30 p.m. – 2:30 p.m.; R 2 p.m. – 3 p.m.

Course Direction and Description

Experiments are at the heart of modern Physics. If the results of an experiment are consistent with the predictions of a theory or model of the physical phenomenon studied in the experiment, then we say we have a measure of understanding of the phenomenon in question. If no agreement is apparent, then either the theory or the experiment is in error. In this course you will carry out four experiments dealing with fundamental physical phenomena. The experiments will involve differing techniques of measurement and analysis. You will be assembling the requisite apparatus, running the experiment, and analyzing the data in an effort to thoroughly judge the quality of the results. In a general way, this course will allow you to quantitatively assess the quality of experimental data and how well the data correspond to theory, an important function in the practice of physical science. Indeed, without an analysis of the errors and uncertainties involved in an experiment, no answer is possible to the question, Do the results of my experiment agree with the theoretical prediction?

In science, the *clarity* of the *presentation* of data, results, and conclusions are almost as important as these factors themselves. In this course you will continue to progress in refining your writing and presentation skills. This Physics laboratory course is a writing emphasis course. During the semester you will produce technical reports describing in your own words an experiment you have personally completed. Data and error analysis will be an integral part of each report. The report's organization and presentation strive for clarity. You will also be scheduled for oral presentations.

During the Physics 310-320 sequence, you will conduct eight of the classic experiments from the 19^{th} and 20^{th} 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 320 is an approved Writing Emphasis course in the WCU General Education program. The writing sessions, laboratory practices and data analysis sessions, and draft review meetings that take place during the semester, as well as the feedback that the faculty give you on your papers and presentations, and the experimental work that you do throughout the semester, are all designed to help you meet the following General Education goals: (Goal #1) students will be able to communicate effectively, (Goal #2) students will be able to employ quantitative concepts and mathematical methods, and (Goal #3) students will be able to think critically and analytically.

In more 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 to the modern physics research laboratory.

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

3. 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 style papers and in person through research talks.

The Experiments

During the semester, you must conduct four experiments from the list of PHY 320 experiments below that you have not conducted previously. You must document those

experiments in a laboratory notebook. You must write and submit research papers for three of the experiments, and prepare a research presentation for the fourth.

PHY 320

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

[1]This experiment requires as a pre-requisite successful completion of the half-life experiment.
[2]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 170/180/310. Your laboratory notebook will serve as the foundation on which your research papers and presentation are built. Your laboratory notebook must be available for review at all times to substantiate any of the claims that you make in your research papers or presentation.

Laboratory Practices and Data Analysis

As in PHY 310, 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 needed to conduct an experiment. You must arrange with me in a timely way to obtain the relevant equipment from inventory.

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. You 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 particularly 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, …I leave it to your imagination.

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. This constitutes unprofessional conduct, and you may also be dismissed 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 be penalized in this 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 permitted. (The experience of calibrating equipment and assembling an apparatus in order to conduct an experiment is critical to your future success in physics and an objective of this course.)

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. Sudol, 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

The research papers that you submit must conform to the standards of research publications in physics and astronomy. The *American Institute of Physics Style Manual* will serve as our primary source for these standards. If the AIP manual does not address a particular issue, consult the instructions for authors for *The Astrophysical Journal*, found at the following URL:

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

Automatic failure will result for papers that have the following obvious faults (this is equivalent to a paper being rejected for publication without review).

- More than three (unique) spelling errors.
- More than two incomplete sentences or sentence fragments.
- Failure to define a variable for a physical quantity. (Mathematical constants, such as π, are exempt from this rule.)
- Duplicate definition. (For example, using the variable F to represent the force of gravity on an oil droplet and the same variable, F, to represent the electrostatic force on the oil droplet. Use subscripts to distinguish variables from one another; for example, F_g and F_e. Similarly, using k to represent a spring constant, then, later, κ to represent the same spring constant.)
- Failure to report a numerical value for all of the physical quantities critical to calculating the final result.

- Failure to follow convention for reporting numerical values.
- Content that appears after the reference section.
- Text in Tables and Figures that is not legible.
- Tables or Figures that violate the margins.
- A Table or Figure caption that does not appear on the same page as the Table or Figure.
- Failure to post any authoritative references.

Draft Review

I will meet with each of you, individually, for 30 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. Besides, if the draft is so poorly constructed and proofread, we may run against the 30 minute limit for commentary.

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.

Research Presentations

Throughout the semester, you will give a presentation 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 those for which you have written papers. 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.

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 presentation a letter grade of A, B, C, D, or F, based on my professional judgment. (My grading criteria are articulated in the paper and presentation 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.

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. Also, the standard to which you are held rises during the course of the semester. Errors or poor practices in an oral presentation noted by the instructor or other Physics faculty should not appear in any later presentation by any student. You are expected to attend all presentations, take notes, and not include any errors or shortcomings in your own presentation once it has been identified during a prior presentation.

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. 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, and, in fact, interfere with that dialog.

Course Schedule

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

Date	Lecture Activities
23 Jan	Laboratory Practices and Data Analysis Session #1: Resolution
30 Jan	Laboratory Practices and Data Analysis Session #2: Modeling Data (non-linear)
6 Feb	Guide for oral presentations Writing Session #1: Conclusion
13 Feb	Presentation #1 & 2: R. G. Seymour (3:20 p.m.), S. Gregor Writing Session #2: Abstract
20 Feb	Presentation #3 & 4: D. Truscott (3:20 p.m.), R. Thomson Writing Session #3: Connecting Statements
27 Feb	Presentation #5 & 6: A. Hardt (3:20 p.m.), A. Bonavita Laboratory Practices and Data Analysis Session #3: Minimizing Uncertainties, Operating Regions
6 Mar	Presentation #7 & 8: B. Pintor. (3:20 p.m.), E. Herrmann Laboratory Practices and Data Analysis Session #4: Experimental Design
12 – 16 Mar	*Spring Break*
20 Mar	Presentation #9 & 10: O. Harris (3:20 p.m.), T. Edwards Improving effectiveness in oral presentations

27 Mar	Presentation #11 & 12: J. Backowski (3:20 p.m.), J. Carnes Additional draft review
3 Apr	Presentation #13 & 14: H. Moss (3:20 p.m.), S. Walters Improving effectiveness in oral presentations
10 Apr	Presentation #15: R. Gallagher (3:20 p.m.)
17 Apr	Presentation #16: C. Wilkins (3:20 p.m.) Additional draft review
24 Apr	Course overview
2 May	Course Overview; Final Papers Due

This syllabus is a minor modification of the one authored by Dr. Jeffrey J. Sudol for the Spring 2017 semester of PHY 320.