

West Chester University
Department of Physics
Physics 245 –Measurement and Uncertainty

Meeting Times: W 3:00 - 4:55 pm
Meeting Place: SEC 366
Instructor: Jeffrey J. Sudol (Dr. Jeff)
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Office email: jsudol@wcupa.edu
Office Hours: M2-3, W11-12, R3-4, F11-12, F2-3

Course Description

This course is designed to strengthen your understanding of measurement and uncertainty in the laboratory setting, as well as learn how to present data in a manner consistent with (i) the standards and conventions of the scientific community and (ii) the concepts of transparency, reproducibility, and credibility.

Required Course Materials

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

Attendance Policy

Attendance is required. If an event beyond your control prohibits you from attending lab, contact the instructor as soon as possible to discuss options. Failure to contact the instructor within two calendar days of an absence will result in zero credit for any assessment missed during the absence.

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

The goals of this course are as follows:

1. The student will become proficient at using a wide range of experimental tools and measurement techniques in a laboratory setting.
2. The student will become proficient at estimating and calculating experimental uncertainties.
3. The student will become proficient at presenting experimental data and its analysis in formats consistent with the standards and conventions of the scientific community and the concepts of transparency, reproducibility, and credibility. These formats include reporting numerical values in text, tables, and graphs.

A short series of lectures and activities on data analysis, four laboratory experiments, data analysis time in lab with the instructor, four assignments (three data summaries and one data presentation), and the feedback provided to you by the instructor on those assignments, are all designed to help you meet these goals.

Program Goals

This course supports the following Physics Program goals, in particular with regard to developing laboratory skills for the research environment, executing experiments, analyzing experimental data, and presenting data in different formats.

Research Skills and Information Literacy

B.S. Physics Majors who graduate from West Chester University will develop the laboratory skills needed to work in a research environment. This skill set will include experiment design and execution, data analysis, familiarity with common measurement instrumentation (e.g. multimeter), and safety practices in a laboratory setting.

Effective Communicators

B.S. Physics Majors who graduate from West Chester University will be well prepared to be effective communicators in the workplace. In particular, graduates will have a working knowledge of Microsoft WORD, EXCEL, and POWERPOINT. In addition, they will be able to present both formal and informal reports in both written and oral mediums.

The Experiments

During the semester, you will conduct four experiments. Following each experiment, you will prepare either a data summary (on paper) or a data presentation (in PowerPoint) in which you will present (i) the data that you obtained during the experiment and (ii) the methods that you used to process that data to arrive at the key result(s) of the experiment.

The Laboratory Notebook

You will maintain a laboratory notebook during this course as you did in PHY 170/180. Your laboratory notebook will serve as the foundation on which your data summaries 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) with the goal of advancing your understanding of how to measure and estimate the uncertainties in a measurement and how to propagate those uncertainties through to the key result(s) of the experiment. In these sessions, I will present the main concepts in the textbook, *An Introduction to Error Analysis*, illustrated with examples.

In each session, I will also present example data in a manner consistent with the standards and conventions of the scientific community and discuss the rationale behind these standards and conventions. These standards and conventions are not arbitrary but allow for the efficient communication of information. (I will also provide you with an abridged version of the *American Institute of Physics Style Manual*, which describes these standards and conventions in great detail.)

Homework

In preparation for each experiment, I will present the theory underlying the experiment, the apparatus for the experiment, and the overall design of the experiment. The following week, you will conduct the experiment in lab. In the meantime, your homework is to answer the following questions:

What physical quantities will you hold constant?

What physical quantities will you change and how?

What is the range over which you will change each physical quantity and in what increments?

What physical quantities will you measure? How?
What is the expected range of each measured quantity?
How many measurements will you take?

Although the homework does not count as a formal assessment, the quality of your data and the success of the experiment will depend on a thoughtful consideration of these questions.

Data Summaries

Following each experiment, you will prepare a data summary, unless you are slated to prepare a data presentation. The summaries that you submit must include: (1) all the data that you obtained during the experiment in a format that conforms to the standards and conventions of scientific journals, (2) an example of each significant, intermediate step in the process through which you arrived at the key result(s) of the experiment, and (3) an example of each significant step taken to arrive at the uncertainty in the key result(s). Brief statements to tie the data and examples together into a coherent picture are encouraged.

Data Presentation

Similarly, the data presentation must include all the data obtained during the experiment and examples of the significant intermediate steps leading to the key result(s), but without the details of the uncertainty analysis. However, all uncertainties must appear with the data, and those uncertainties must track through to the key result(s). The fundamental difference here is the format. The goal is to present the data, its analysis, and the result(s) in a visual medium for a live audience of scientists. Presentations are limited to 10 minutes. The presentations will serve as a launch point for a group discussion about how best to present data. Again, brief statements to tie the data and examples together into a coherent picture are welcome.

Assessment

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

- (3) Data Summaries 25% each
- (1) Data Presentation 25%

I will assign each summary and presentation a letter grade of A, B, C, D, or F, using (+) and (-) to achieve a resolution of 15 grades, based on my professional judgment, which is further articulated in grading rubrics that I will provide you.

Student Learning Outcome	Activities	Assessments
experimental tools and measurement techniques	<ul style="list-style-type: none"> • (Instruction) Prep for each Experiment • Answering homework questions • Conducting the experiments 	Data Summaries Data Presentation
estimating and calculating uncertainties	<ul style="list-style-type: none"> • (Instruction) Laboratory Practices and Data Analysis Sessions • Answering homework questions • Conducting the experiments • Preparing Data Summaries and Presentations • Engaging in discussions following Data Presentations • Reviewing instructor feedback on Data Summaries and Presentations 	Data Summaries Data Presentation
presenting experimental data and its analysis	<ul style="list-style-type: none"> • (Instruction) Laboratory Practices and Data Analysis Sessions • Answering homework questions • Preparing Data Summaries and Presentations • Engaging in discussions following Data Presentations • Reviewing instructor feedback on Data Summaries and Presentations 	Data Summaries Data Presentation

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 having an adverse effect on the results of the assessments or the schedule of assessments.

A Misconception

Students (as well as the general public) often 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. Most of the experiments that you will conduct in this course require no more than 30 minutes of active attention to acquire data; some, as little as 10 minutes.

Course Schedule

Date	Lecture Activities
Jan. 24	Laboratory Practices and Data Analysis Session #1: Uncertainties in Measurement
Jan. 31	Laboratory Practices and Data Analysis Session #2: The Central Limit Theorem Prep for Experiment #1
Feb. 07	Experiment #1: The Wavelengths of the Balmer Series of Spectral Lines
Feb. 14	Laboratory Practices and Data Analysis Session #3: Modeling Data (linear regression) [Data Analysis Time with the instructor]
Feb. 21	Data Presentations (all groups) Prep for Experiment #2 [Data Summary for Experiment #1 Due]
Feb. 28	Experiment #2: Planck's Constant from the Photoelectric Effect

Course Schedule (continued)

Date	Lecture Activities
Mar. 06	[Data Analysis Time]
Mar. 13	<i>No Class - Spring Break</i>
Mar. 20	Group #1 Data Presentation Prep for Experiment #3 [Data Summary Experiment #2 Due]
Mar. 27	Experiment #3: The Energy Split in the Sodium Doublet
Apr. 03	[Data Analysis Time]
Apr. 10	Group #2 Data Presentation Prep for Experiment #4 [Data Summary Experiment #3 Due]
Apr. 17	Experiment #4: The Half-Life of Ba²³⁸
Apr. 24	[Data Analysis Time]
May 01	Group #3 Data Presentation [Data Summary Experiment #4 Due]

A brief description of the content of each Laboratory Practices and Data Analysis Sessions follows.

Session #1: How do we assign an uncertainty to a measurement? Read uncertainty, estimates of uncertainty, measurements of uncertainty (mean, standard deviation), propagating uncertainties, the largest contributor to uncertainty and negligible uncertainties.

Session #2: Why do we repeat measurements? How many measurements are sufficient? The meaning of standard deviation, illustrated. The difference between "standard deviation" and "standard deviation of the mean", illustrated. The central limit theorem. Outliers and Chauvenet's criterion. Technique matters.

Session #3: How do we fit a "model" to the data? Linearization. Linear regression. Peak finding methods, fitting a function to data. Chi-squared.

Academic and Personal Integrity

It is the responsibility of each student to adhere to the university's standards for academic integrity. Violations of academic integrity include any act that violates the rights of another student in academic work, that involves misrepresentation of your own work, or that disrupts the instruction of the course. Other violations include (but are not limited to): cheating on assignments or examinations; plagiarizing, which means copying any part of another's work and/or using ideas of another and presenting them as one's own without giving proper credit to the source; selling, purchasing, or exchanging of term papers; falsifying of information; and using your own work from one class to fulfill the assignment for another class without significant modification. Proof of academic misconduct can result in the automatic failure and removal from this course. For questions regarding Academic Integrity, the No-Grade Policy, Sexual Harassment, or the Student Code of Conduct, students are encouraged to refer to the Department Undergraduate Handbook, the Undergraduate Catalog, the Ram's Eye View, and the University website at www.wcupa.edu.

Students with Disabilities

If you have a disability that requires accommodations under the Americans with Disabilities Act (ADA), please present your letter of accommodations and meet with me as soon as possible so that I can support your success in an informed manner. Accommodations cannot be granted retroactively. If you would like to know more about West Chester University's Services for Students with Disabilities (OSSD), please visit them at 223 Lawrence Center. Their phone number is 610-436-2564, their fax number is 610-436-2600, their email address is ossd@wcupa.edu, and their website is at <https://www.wcupa.edu/universityCollege/ossd/>. In an effort to assist students who either receive or may believe they are entitled to receive accommodations under the Americans with Disabilities Act and Section 504 of the Rehabilitation Act of 1973, the University has appointed a student advocate to be a contact for students who have questions regarding the provision of their accommodations or their right to accommodations. The advocate will assist any student who may have questions regarding these rights. The Director for Equity and Compliance/Title IX Coordinator has been designated in this role. Students who need assistance with their rights to accommodations should contact them at 610-436-2433.

Excused Absences Policy

Students are advised to carefully read and comply with the excused absences policy, including absences for university-sanctioned events, contained in the WCU Undergraduate Catalog. In particular, please note that the "responsibility for meeting academic requirements rests with the student," that this policy does not excuse students from completing required academic work, and that professors can require a "fair alternative" to attendance on those days that students must be absent from class in order to participate in a University-Sanctioned Event.

Reporting Incidents of Sexual Violence

West Chester University and its faculty are committed to assuring a safe and productive educational environment for all students. In order to comply with the requirements of Title IX of the Education Amendments of 1972 and the University's commitment to offering supportive measures in accordance with the new regulations issued under Title IX, the University requires faculty members to report incidents of sexual violence shared by students to the University's Title IX Coordinator. The only exceptions to the faculty member's reporting obligation are when incidents of sexual violence are communicated by a student during a classroom discussion, in a writing assignment for a class, or as part of a University-approved research project. **Faculty members are obligated to report sexual violence or any other abuse of a student who was, or is, a child (a person under 18 years of age) when the abuse allegedly occurred to the person designated in the University Protection of Minors Policy.** Information regarding the reporting of sexual violence and the resources that are available to victims of sexual violence is set forth at: <https://www.wcupa.edu/admin/diversityEquityInclusion/sexualMisconduct/default.aspx>

Inclusive Learning Environment and Anti-Racist Statement

Diversity, equity, and inclusion are central to West Chester University's mission as reflected in our [Mission Statement](#), [Values Statement](#), [Vision Statement](#) and [Strategic Plan: Pathways to Student Success](#). We disavow racism and all actions that silence, threaten, or degrade historically marginalized groups in the U.S. We acknowledge that all members of this learning community may experience harm stemming from forms of oppression including but not limited to classism, ableism, heterosexism, sexism, Islamophobia, anti-Semitism, and xenophobia, and recognize that these forms of oppression are compounded by racism. Our core commitment as an institution of higher education shapes our expectation for behavior within this learning community, which represents diverse individual beliefs, backgrounds, and experiences. Courteous and respectful behavior, interactions, and responses are expected from all members of the University. We must work together to make this a safe and productive learning environment for everyone. Part of this work is recognizing how race and other aspects of who we are shape our beliefs and our experiences as individuals. It is not enough to condemn acts of racism. For real, sustainable change, we must stand together as a diverse coalition against racism and oppression of any form, anywhere, at any time.

Resources for education and action are available through WCU's [Office for Diversity, Equity, and Inclusion](#) (ODEI), DEI committees within departments or colleges, the student [ombudsperson](#), and centers on campus committed to doing this work (e.g., [Dowdy Multicultural Center](#), [Center for Women and Gender Equity](#), and the [Center for Trans and Queer Advocacy](#)). Guidance on how to report incidents of discrimination and harassment is available at the University's [Office of Diversity, Equity and Inclusion](#).

Emergency Preparedness

All students are encouraged to sign up for the University's free WCU ALERT service, which delivers official WCU emergency text messages directly to your cell phone. For more information, visit www.wcupa.edu/wcualert. To report an emergency, call the Department of Public Safety at 610-436-3311.

Electronic Mail Policy

It is expected that faculty, staff, and students activate and maintain regular access to University provided e-mail accounts. Official university communications, including those from your instructor, will be sent through your university e-mail account. You are responsible for accessing that mail to be sure to obtain official University communications. Failure to access will not exempt individuals from the responsibilities associated with this course.