

PHYS 461 Modern Physics Lab, Spring 2022

University of Tennessee, Knoxville



Meeting Time and Place: Nielsen 303 MW 9:00 – 12:00 (6 contact hours)

Course Credit Hours: 3

Faculty Contact Information

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Course Description/Information: Introduction to fundamental and modern techniques in experimental physics and to the theory and practice of measurement and data analysis. Selected experiments in nuclear, atomic, molecular and solid-state physics, and modern optics. Prerequisites: PHYS 361 and either PHYS 250, or PHYS 411.

Value Proposition: This course is essentially the capstone experimental experience for physics majors. The laboratory includes specialized equipment for performing experiments to investigate diverse physical phenomena. The experiments rely on knowledge garnered from across the undergraduate curriculum. This course is a research experience, going beyond simply following detailed step-by-step instructions. Together, we consider different approaches and improvements to the experiments, as well as sources of uncertainty. We take responsibility for ourselves, others, and the equipment when trouble shooting, or considering improvements. There is also a focus on scientific communication through short reports, leading into a longer written report and oral presentation at the end of the semester.

Student Learning Outcomes/Objectives: After successful completion of this course, you will be able to:

- 1) Make measurements with complex equipment, including making and applying calibrations. You will be able to use your own judgment in making observations and reading results, for example, from oscilloscopes.
- 2) Analyze data, including making error estimates and propagating these to the final results.
- 3) Communicate the physics motivation, experimental methods including descriptions of equipment used, and results, in writing and through oral presentations.

- 4) Illustrate results using graphs with error bars, and in clear tables.
- 5) Extract information from graphs using fits.
- 6) Keep a laboratory journal that includes notes about the physical concepts being studied and progress in taking data.

Learning Environment: The laboratory is a collaborative environment. It is important that everyone respects each other, as well as the health and safety rules in place to protect all of us. Students typically work in pairs. You are expected to collaborate with your lab partner in almost all aspects of the course except writing a final report. Being able to collaborate with others effectively is an important skill.

Course Communications: Communication will be in-person in the laboratories, through e-mail, through Canvas, and via Zoom. Grading will be communicated through rubrics and comments on laboratory reports. Read these carefully and contact us with any questions. Please monitor your e-mail and Canvas regularly. For technical issues, contact the OIT HelpDesk via phone (865) 974-9900 or online at <http://help.utk.edu/>.

How to Be Successful in This Course: This course requires the completion of seven experiments. These are typically the seven experiments listed below, but one, or two, may be replaced with other experiments, usually those listed as “other experiments.” Usually these alternates are added to the rotation later in the semester.

Students are expected to attend class at least 6 hours per week, summed over the scheduled class times and outside of these times. Students should arrive promptly for scheduled sessions. The laboratory time can be used for background reading, as well as taking data and graphing results. However, this semester we request that students prioritize working on lab-based tasks in the lab, work on reading and writing tasks outside of the laboratory, where possible. While collecting data, it is reasonable that students work on **writing reports, although generally these should be worked on outside of lab time.**

The best way to be successful in the course is to perform the experiments carefully, taking time with calibrations where needed, or for the temperature to equilibrate where needed. Most of the experiments will give poor results if rushed. Therefore, in order to complete all the experiments before the end of semester, when final exams become a priority, it is important to spend sufficient time in the laboratory and/or analyzing the data throughout the semester. The class is allocated six hours a week. Especially this semester, those six hours may not be during the normal class time, but you should endeavor to spend at least six hours a week working toward completing experiments and analyzing data. As we will be scheduling meetings with pairs of students, it is important that you come to those sessions prepared. This means that you should have read the handout for the experiment that you are starting, and you should have looked through all of the material in the module on Canvas relating to that experiment. All the handouts can be found here: <http://www.phys.utk.edu/physlabs/modern-physics/index.html> and on Canvas under each module.

Handing reports in on time is essential to get early feedback on your work. These reports take significant time to grade. We, the instructors, usually grade and return reports within a week of receiving them, especially for the first reports, but this may sometimes be closer to two weeks. We use a rubric for grading, so students know where they lost points, and we also write comments on the report. Not all the comments will result in lost points, some are grammatical corrections, or suggestions of a stylistic nature.

Safety first: We have tried to minimize electrical and radiation hazards, but there are always possibilities for injury. Follow all safety procedures for handling lasers, the x-ray machine, radioactive materials, and high voltage sources. **Be careful with the equipment.** Don't make connections unless you understand what you're doing. **Don't play with the equipment with "Idle Hands."** Read the equipment manuals.

Be courteous: Return tools, equipment, etc. to their proper place. Don't remove equipment from someone else's experiment for use on your own (without asking first).

Texts/Resources/Materials:

Students are required to purchase a laboratory notebook. A hardbacked version is recommended as there are few open hard surfaces that students can use for writing. If you prefer to keep a digital laboratory notebook, that will also be acceptable. You may want to make sketches, so think about using software that allows text and drawings.

The Experiments:

1. Zeeman Effect
2. Compton Scattering
3. X-Ray Bragg Diffraction
4. Temperature Dependent Lifetimes of Fluorescence from a Phosphor
5. Nuclear magnetic resonance
6. Hall Effect
7. The Speed of Light--Rotating Mirror Version

Other Experiments that may be available

1. Cavendish Experiment--Determination of Gravitational Constant
2. Muon lifetime
3. Cesium Heatpipe Experiment

Link to descriptions for all experiments plus some other useful information:

<http://www.phys.utk.edu/labs/modphys/>

Assignments

The assignments for this course are **1) brief reports, 2) one detailed report, and 3) final presentation**. In addition, you need to turn in **notes from each lab**.

1) Brief reports

There will be six brief reports this semester. For a brief report, you and your lab partner alternate in reporting. **You earn 100% of points from reports where you are the lead author. You earn 25% of points from reports where your lab partner is the lead author.** You are strongly encouraged to help your lab partner write the reports where you are not the lead author.

A brief report which consist of the following:

1. A title page listing the course name and number, name of the experiment, the date performed, and the name of your lab partner.
2. A short introduction **including a few sentences on the physical process being investigated** and what you want to find. It should be clear that you understand the experimental process and the underlying physics.
3. An **original** diagram of the experiment with all the associated instrumentation and wiring. This should be clear, whether drawn by hand (with a ruler etc.) or on a computer.
4. At least two graphs of representative data and analysis of data.
5. A summary of the analysis, final results, and error analysis—identify the sources of errors and their significance in the analysis of results. Calculate/estimate the expected errors in the final quantity, where appropriate.
6. Raw data should be available to instructors upon request (you do not need to append pages of tabulated data). **Please do not send us 10's of pages of raw data or graphs.**

Please submit brief reports via Canvas as a pdf-file. Please make sure that the file size is not excessively large.

2) Detailed Report

One experiment will be selected in consultation with the instructor to be reported on in-depth. This report will also be used for the final presentation. Unlike the brief reports, you should write a detailed report **independent** of your lab partner.

The detailed report will consist of the following:

1. A title page listing the course name and number, name of the experiment, the date performed, and the experiment collaborators.
2. An introduction section in which the overall experiment and its objectives are described.
3. A description of the pertinent theory that supports the experiment to demonstrate your understanding of the principles being studied. You do not need to include derivations but do include the main equations used.

4. A description of the experimental apparatus and instrumentation, complete with a schematic diagram and description of the purposes of each piece of equipment.
5. Presentation of results section. This should include the graphs and/or tables of the raw data.
6. Analysis of Results—Description of the analysis of results including calculations and graphical analyses.
7. Discussion of results with error analysis—identify the sources of errors and their significance in the analysis of results. Calculate/estimate the expected errors in the final quantity, where appropriate.

Some tips/guidelines in writing both brief and detailed reports

You should write your report for a physicist who understands the physics behind your work, but needs to be told exactly what went on and how it turned out.

A short introduction should explain what you tried to do and why. **Little credit will be given for long histories of the experiment or theoretical derivations that can be found in the references or handouts.** Give a brief explanation of the formulae you used and how you used them. Describe any unique characteristics of the experiment and present derivations of non-standard formulas. **Do NOT copy the write-up or other sources.** That is plagiarism and unacceptable. Use your own words. You should not look at the writeup while you write your introduction or you will be tempted to just paraphrase the writeup.

The experimental section should give enough information to enable someone to reproduce your results. **This should NOT take the form of a list** of instructions, but should be in the **past** tense, describing what was done. You should: Show the equipment used and their interconnections, Explain the data acquisition procedures, Describe the statistical uncertainties and an explanation of how they were assigned. Discuss possible sources of systematic error and how you handled them.

The analysis section should show how the data and their uncertainties (random and systematic) produce the final results and their uncertainties. Present graphs or tables of derived quantities with their associated uncertainties. Show how the errors were assigned.

The results section should give a concise listing of the major findings of the experiment. Comparisons between your results and theoretical expectations or other experimental values should be made. Typically, we discuss an agreement to within 1 sigma, or 2 sigma. You may also want to comment in the end of this section on how the experiment could be improved or what should you have done differently.

3) Final Presentation

1. Presentations will be during the final exam period. All students will attend the presentation session.
2. The presentations will be given in pairs. Each student will contribute equally, typically the time is split evenly between students.
3. Each presentation will be 10 minutes, with approximately 2-5 minutes for questions.

4. Students should expect basic physics questions relating to any of the experiments performed during the semester during the presentation session.
5. A handout on presentation skills will be provided near the end of the semester.

4) Notes from labs

Everybody should keep a lab notebook and take notes of each lab. Note-taking is an important skill. Your notes do not need to look nice but they must be detailed, allowing you or somebody else to reproduce the experiment later and/or to troubleshoot a problem if something went wrong. You should submit these notes even if you are not the lead author responsible for the brief report on this lab. Two different components of note-taking will be evaluated: 1) theoretical preparation for the lab, 2) notes taken during the experiments. You should scan these notes and submit them after each lab period via Canvas as a pdf-file (as the brief reports). Please make sure that the file size is not excessively large.

Due dates for brief reports

Laboratory reports are due on the day shown in the table below and must be handed in promptly to progress through the experiments. Any student who is delinquent by two reports cannot move on to their next experiment. For example, you need to hand in your first short lab report before you can start your third experiment. Reports handed in after the due date will have two points taken off per week late.

Day	Date	Note
Monday	1/24/22	First day of class.
Wednesday	1/26/22	
Monday	1/31/22	
Wednesday	2/2/22	
Monday	2/7/21	
Wednesday	2/9/22	First Report Due
Monday	2/14/22	
Wednesday	2/16/22	
Monday	2/21/22	
Wednesday	2/23/22	Second Report Due
Monday	2/28/22	
Wednesday	3/2/22	
Monday	3/7/22	

Wednesday	3/9/22	Third Report Due
Spring Break		
Monday	3/21/22	
Wednesday	3/23/22	
Monday	3/28/22	
Wednesday	3/30/22	Fourth Report Due
Monday	4/4/22	
Wednesday	4/6/22	
Monday	4/11/22	
Wednesday	4/13/22	Fifth Report Due
Monday	4/18/22	
Wednesday	4/20/22	
Monday	4/25/22	
Wednesday	4/27/22	
Monday	5/2/22	
Wednesday	5/4/22	
Monday	5/9/22	Last Scheduled Class Session
Friday	5/13/22	3:30-6:30 pm exam slot
Monday	5/16/22	10:30-12:45 exam slot

Grading brief reports:

Each short report will be graded using the grading slip copied below. Note that the report is graded out of a total of 40 points. Please note, if you do not include something that is on the grading slip, we cannot give you points for that item.

Example Grading Slip for Short Reports

Report

Introduction

Physical mechanism being investigated and background 5

Methods

Original diagram of equipment 2

Description of major equipment 3

Description of experimental procedure 2

Results

Careful measurement and analysis resulting in high quality data 12

Description of data analysis 3

Representative data graph 2

Error estimation propagated to final results 8

Summary graph or Table 3

TOTAL 40

Notes

Notes about the physics concept behind experiment 5

Notes to track progress of the experiment 5

TOTAL 10

Grades

Final grades will be calculated as follows:

Component of Grade	Weight
Reports	60%
Notes	15%
Final Report	15%
Presentation	10%
Total	100%

A	90 and above
A-	87 and above
B+	83 and above
B	80 and above
B-	77 and above
C+	73 and above
C	70 and above
C-	67 and above
D+	63 and above
D	60 and above
D-	57 and above
F	below 57

University Policies:

Academic Integrity: “An essential feature of the University of Tennessee, Knoxville is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.”

University Civility Statement: Civility is genuine respect and regard for others: politeness, consideration, tact, good manners, graciousness, cordiality, affability, amiability and courteousness. Civility enhances academic freedom and integrity, and is a prerequisite to the free exchange of ideas and knowledge in the learning community. Our community consists of students, faculty, staff, alumni, and campus visitors. Community members affect each other’s well-being and have a shared interest in creating and sustaining an environment where all community members and their points of view are valued and respected. Affirming the value of each member of the university community, the campus asks that all its members adhere to the principles of civility and community adopted by the campus: <http://civility.utk.edu/>.

Physics and Astronomy Civility Statement: As a department, we are committed to creating an environment that welcomes all people, regardless of their identities. We value the diversity that enriches our department. We understand the importance of free and open dialogue that includes the free exchange of ideas. We do not tolerate uncivil speech or any form of discourse that infringes on others’ rights to express themselves, or has a negative impact on their education, or work environment. We actively promote an environment of collegiality and an atmosphere of mutual respect and civility. We understand that respect includes being considerate of others’ feelings, circumstances, and their individuality. We recognize the necessity of a civil community in realizing the potential of individuals in teaching, learning, research, and service. We believe these values extend beyond the department into our work within physics regionally, nationally, and internationally, as well as work and studies in the university, and the broader community. We

encourage all members of the department to intervene and report any incidents involving bigotry, or that violate the university code of conduct.

Reporting: Anyone who experiences or observes any such incident is encouraged to report it to the Department Head or one of the Associate Heads. Students can also speak to any faculty or staff member with whom they feel comfortable. Incidents that involve sexual harassment or stalking will be reported to the office of Title IX under mandatory reporting requirements.

Additional resources and reporting available at: <http://www.phys.utk.edu/about/civility-community.html>

Disability Services: “Any student who feels s/he may need an accommodation based on the impact of a disability should contact Student Disability Services in Dunford Hall, at 865-974-6087, or by video relay at, 865-622-6566, to coordinate reasonable academic accommodations.”

Your Role in Improving Teaching and Learning Through Course Assessment:

At UT, it is our collective responsibility to improve the state of teaching and learning. During the semester, you may be requested to assess aspects of this course either during class or at the completion of the class. You are encouraged to respond to these various forms of assessment as a means of continuing to improve the quality of the UT learning experience.

Key Campus Resources for Students:

- [Center for Career Development](#) (Career counseling and resources; HIRE-A-VOL job search system)
- [Course Catalogs](#) (Listing of academic programs, courses, and policies)
- [Hilltopics](#) (Campus and academic policies, procedures and standards of conduct)
- [OIT HelpDesk \(865\) 974-9900](#)
- [Schedule of Classes/Timetable](#)
- [Student Health Center](#) (visit the site for a list of services)
- [Student Success Center](#) (Academic support resources)
- [Undergraduate Academic Advising](#) (Advising resources, course requirements, and major guides)
- [University Libraries](#) (Access to library resources, databases, course reserves, and services)

The instructor reserves the right to revise, alter or amend this Syllabus as necessary. Students will be notified in writing / e-mail of any such changes.