Syllabus

Physics 541 Advanced Experimental Physics I – Fall 2021

Instructor: Dr. Yanwen Wu

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Official Class Meeting Times:

Mon., Wed. 2:20 - 5:10 PM, PSC labs 506 (Lecture) and 511 (Lab)

Office hours: During lab periods or by appointment

Bulletin description:

PHYS 541 - Advanced Experimental Physics I

Credits: 4

Continuation of PHYS 310. Optical apparatus (telescope, microscope, interferometer) and advanced project planning including equipment design and budgeting.

Prerequisites: Grade of C or better in PHYS 310

Text:

Optics -Eugene Hecht (5th edition, Hardcover, Pearson/Addison Wesley, ISBN 0-13-397722-6)

Optional Text:

Building Scientific Apparatus - Moore, Davis, Coplan, and Greer (4th edition, hardback, ISBN 978-0521878586)

Class expectations, operation:

This 4 credit hour class meets 6 hours per week: At 3 hours additional outside of class for each “credit hour”, the total time spent in the lab/out of class should total 6 + 12 = 18 hours. I will be collecting and grading laboratory notebooks monthly in order to assess both your effort and your accomplishments. More detail on what should be in the laboratory notebooks will be given below.

Mondays will include of an overview “lecture” at the beginning of class, and a class-wide discussion on Wednesdays at the beginning of class, with participation in the discussion graded as part of the weekly homework grade.

Graduate students attending the class will be expected to do extra work. Details will be listed in the Grading section. The extra work is required to receive an A in the course. Failure to complete the extra work will result in the deduction of one letter grade.

General Comments: Academic Integrity, Disability policy, Excessive Absences

Every student has a role in maintaining the academic reputation of the university. It is imperative that you refrain from engaging in plagiarism, cheating, falsifying your work and/ or assisting other students in violating the Honor Code.

Students with Disabilities: The University of South Carolina provides high-quality services to students with disabilities, and we encourage you to take advantage of them. Students with disabilities needing academic accommodations should: (1) Register with and provide documentation to the Student Disability Resource Center in LeConte College Room 112A, and (2) Discuss with the instructor the type of academic or physical accommodations you need. Please do this as soon as possible. All course materials are available in alternative format upon request.

Students are obligated to complete all assigned work promptly, to attend class regularly, and to participate in whatever class discussion may occur.

Absence from more than 10 percent of the scheduled class sessions, whether excused or unexcused, is excessive and the instructor may choose to exact a grade penalty for such absences. It is of particular importance that a student who anticipates absences in excess of 10 percent of the scheduled class sessions receives prior approval from the instructor before the last day to change schedule as published in the academic and refund calendars on the registrar's Web site.

Learning Outcomes

General:

1. Work with basic optical components, such as prisms, mirrors, and lenses.
2. Construct and deploy optical apparatus to acquire data in an experiment, including a microscope, a telescope, an interferometer, and a spectrometer.
3. Understand how to design and layout an experiment that includes references to prior work, a component list, a schematic, and a project budget.
4. Assess potential sources of error and analyze uncertainties.

Experimentation:

1. The student will be able to design and construct experiments to demonstrate basic principles of optics
2. The student will know how to handle a variety of experimental components and to integrate them together to create an optics experiment
3. The student will know how to employ hand-held tools (screwdriver, hex-driver, torque wrench, etc.) to assemble various components into an optical experiment
4. The student will know how to measure the outcome of an experiment with various detectors combined with oscilloscopes and lock-in amplifiers.
5. The student will know how to design and plan an experiment to study a problem that has been contextualized via studying the relevant scientific literature.

Theory, Analysis, and Problem Solving:

1. The student will be able to develop an optics background by a variety of methods, including reading the textbook, solving problems from the textbook, and by consulting online media, including the fundamental optics literature.
2. The student will be able to express and communicate understanding of semi-classical optics theory through mathematical problem solving.
3. The student will be capable of solving a range of problems in optical physics to cement his/her understanding of how to apply theoretical optics concepts to different experimental optics situations.
4. The student will know how to analyze acquired experimental data using mathematical functions from optics theory via computer software (Mathematica, or other) with numerical fitting and proper error analysis.

Communication, Interaction, and Dissemination:

1. The student will be able to work and communicate with colleagues as a member of a team through creation of optics experiments.
2. The student will be able to assemble experimental results and analysis into a written form (journal manuscript), placing those results in the context of prior work, and drawing conclusions from their analysis.
3. The student will be able to communicate experimental results and analysis via oral presentation.

Grading

Weekly problem sets (9 in total + weekly participation) - **15%**

- Context: explanation of why the problem is relevant - 20%
- Solution: Well-explained solution with each step documented - 50%
- Assessment: is the solution reasonable? why/why not? - 20%
- Neatness: Are the solutions typed? Are the equations typeset? - 10%
- **Graduate students will have extra components in the problem sets involving open-ended questions to assess their deeper understanding of the problems.**

Take-Home Exams (2 of them) - **2 x 20 % = 40%**

- Experimental design: Is there a photograph and schematic of the experiment? Is it detailed enough for someone to reproduce it on their own? - 25%
- Data and its presentation: Is there data on the experiment? Is it well-presented, in either a table or graph, with clear labels and explanations of what the data is? Are there error bars? - 25%
- Analysis: Is the data analyzed? - Is a model used to try and understand the shape of the data? Is there a proper treatment of uncertainty? How did you eliminate systematic errors?) - 25%
- Conclusions and quality: Did you explain what you learned from the experiments? Is the report clearly written? Did you address systematic errors and how they affect the conclusions? Have you discussed the physics underlying the experiment clearly? - 25%
- **Exam write up from graduate students will be graded more strictly in accordance with peer-reviewed journals standards.**

Laboratory notebook (A shared Dropbox folder will be used to monitor progress) **- 25%**

- Experimental effort: Did you start with a hypothesis and write it down? Did you document in writing that you were in the laboratory working on the experiments for the course - 30%
- Data: Did you acquire experimental data, documented as numbers, an image, or acquired electronic data - 30%
- Analysis: Did you analyze your data with a theoretical model? Did you draw a conclusion? Does the experiment agree or disagree with your starting hypothesis? - 30%
- Detail/quality: Is your writing neat? If a diary, did you think about what you were writing. Did you come back to address questions? Is it obvious you read through your notes? Do your entries tell a coherent story? - 10%

Final presentation on project plan - **20% (for undergraduate students), 10% for graduate students**

Graduate students are expected to submit a two-page abstract, in the style of a conference submission, in addition to the oral presentation. – 10%

Assignment	**Undergraduate Students**	**Graduate Students**
Weekly Problem Sets	**15%**	**15%**
Exams (2 @ 20%)	**40%**	**40%**
Laboratory Notebook	**25%**	**25%**
Final Presentation	**20%**	**9%**
Two page abstract	**-**	**11%**
Total	**100%**	**100%**

Grading scale:

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> 90% = A

85-89% = B+

80-84% = B

75-79% = C+

70-74% = C

65-69% = D+

60-64% = D

<60% = F

Course Schedule - Tentative

Module 1: Optics and How to design/build experiments

Week 1 –Aug 23/25 - Geometric Optics (Newton's Optics)

- Class Overview
- Working with optics: Sources, Optics, Optic Mounting, Opto-Mechanics
- Newton Proposition 1, Theorem 1, Experiments 1-2
- **Aug 25 – Last day to drop/add w/o "W" grade**

Week 2 – Aug 30/Sept 01 - Geometric Optics (Newton's Optics - thin lenses)

- Finish up Newton's Optics experiments
- Image formation with lenses - combinations of lenses, magnification (Hecht Chapter 5)
- **Sep 01 - Problem set #1 due (start of class)**

Week 3 – Sep 06/08 - Geometric Optics (Thin lenses and the telescope)

- **Sep 06 – Labor Day (no classes)**
- Combinations of lenses: build a 2-lens telescope (Hecht Chapter 5)
- Using hypotheses with experiments. (distinction between “trying stuff” and “thinking before doing”)
- **Sep 08 - Problem set #2 due (start of class)**
- **Sep 06 - Last day to apply for May Graduation**

<u>Week 4 – Sep 13/15 - Geometric Optics (Thin lenses - deeper dive)</u>

- Lenses and stops, magnification (Hecht Chapters 5-6)
- Analyze your telescope
- **Sep 15 - Problem set #3 due by email (start of class)**

<u>Week 5 – Sep 20/22 - Geometric Optics</u>

- Other optical systems - obtaining and analyzing quantitative data
- **Sep 22 - Problem set #4 due (start of class)**
- <u>**Start Take Home Exam #1**</u>

<u>Week 6 – Sep 27/29 - Geometric Optics (cont.)</u>

- Work on exp and Exam #1

<u>**Module 2: Physical Optics**</u>

<u>Week 7 – Oct 04/06 - Interference/Interferometers</u>

- <u>**Oct 04 - Take Home Exam #1 due (by email, PDF format)**</u>
- What is interference? (Hecht Chapters 7,9), Interferometers (Hecht Chapter 9)
- Michelson Interferometer
- **Th-F Oct 07-08Fall Break (no classes)**

<u>Week 8 – Oct 11/13 - Interference (cont.)</u>

- Continue work on interferometer exp.
- **Oct 13 - Problem Set # 5 due (start of class)**

<u>Week 9 – Oct 18/20 - Interference/Diffraction</u>

- Fraunhofer Diffraction (Hecht Chapter 10)
- **Oct 20 - Problem Set # 6 due (start of class)**

<u>Week 10 – Oct 25/27 Diffraction</u>

- Diffraction and Fourier analysis
- **Oct 27 - HW #7 due (Topic of research, tentative title, at least free relevant references)**

<u>Week 11 – Nov 01/03 - Diffraction (cont.)</u>

- Diffraction Gratings (Hecht Chapter 10)
- <u>**Start Take Home Exam #2**</u>

<u>Week 12 – Nov 08/10 - Physical Optics</u>

- Work on exp and Exam #2

<u>**Module 3: Experimental Project Planning**</u>

<u>Week 13 – Nov 15/17 – Choosing Project Topic</u>

- Conduct literature research and find background articles
- <u>**Nov 15 - Take Home Exam #2 due (by email, PDF format)**</u>

<u>Week 14 – Nov 22/24 - Project Planning</u>

- Finalize equipment and specs, work with vendors, catalogs, and get vendor quotes
- **Nov 24 - HW # 8 due (Project hypothesis, reference list, and a draft experiment layout/parts, equipment list)**
- <u>**Nov 24-28 – Thanksgiving (no classes)**</u>

<u>Week 15 – Nov 29/Dec 01 - Mechanical drawing, project layout; finalize budget</u>

- Timeline for the project. Assessing pitfalls. What are the ‘gotcha’s’ for a project?
- Assemble final project details, prepare final project presentation
- <u>**Dec 01 - Last Day for this class**</u>

Monday Dec 06, 2021 at 12:30 PM (Final Exam Period for PHYS541)

- Give final presentation during final exam period

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Special changes during Covid-19 Period:

All written materials, such as lab notebooks, HWs, exams, shall be turned in electronically. I will create a Dropbox shared folder for each student. Students should deposit their work into the shared folder on the due date. Graded work will also be returned in the same folder. Student can complete the handwritten tasks with pen and paper and scan their final work with an image scanning app. The preferred format of the hand-in work is PDF.