PHY 410 – Optics

Fall 2022

Instructor Information

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Office: SECC 365

Office Hours:

Monday - 10 am to 12 pm & 1 pm to 2 pm
Tuesday - 1:45 pm to 2:45 pm
Thursday - 1:45 pm to 2:45 pm

Course Materials

Textbook: Peatross, J. and Ware, M. (2015 edition) *Physics of Light and Optics*
A PDF of this book is available for free at optics.byu.edu. Information is provided on the site to purchase a low-cost version.

Computer: Weekly assignments involving programming with Matlab will be assigned. Students need either personal computer that can run Matlab or access to a WCU computer with Matlab installed. If interested, ask instructor about WCU computer labs with Matlab computers.

Recommended Text: Attaway, S. (2017). *Matlab: A Practical Introduction to Programming and Problem Solving.* Butterworth-Heinemann.

Software

This course relies heavily on Matlab. The University has a site license for Matlab making it free for all students. To install Matlab on your personal computer, use the WCU portal on Mathworks. Matlab is also available on certain computers around campus and can be accessed through RamCloud.

Course Description

Geometrical and physical optics. Reflection and refraction at surfaces, lenses, interference and diffraction, and polarization.

Course Student Learning Outcomes

** First Exam Material **

Student will be able to …

- State the law of reflection and Snell's Law. Use a diagram to clearly define all angles. State the difference between the s-wave and the p-wave.
- Define Fresnel Coefficients (equations 3.20, 3.21, 3.22, and 3.23 – just the definitions) and why they are useful.
- State the definition of Reflectance and Transmittance (eq 3.26 and 3.30).
- State the expression for Brewster's angle (eq 3.26) and explain why it occurs.
- State the expression for the critical angle (eq 3.38) and describe total internal reflection
- Derive the Wave Equation from Maxwell Equations
- If provided with Figure 4.1, be able to explain eqns 4.4, 4.5, 4.6 and 4.7.
- Describe a Fabry-Perot interferometer and a Fabry-Perot etalon.
- Describe how anti-reflection coatings work

- State the mathematical expression for a plane wave (both real and complex) and describe the meaning of all the variables involved
- State the parts of the electro-magnetic spectrum (Figure 2.1) in terms of increasing energy
- State the constitutive relation for polarization amplitude and the applied electric field (eq 2.16)
- State the relationship between the index of refraction and the susceptibility. State the physical relevance of each. (eq 2.18)
- Be able to describe the Lorentz Model of Dielectrics. Your description should include a sketch similar to Figure 2.4, the equation 2.31, 2.16, and 2.32, and the resulting response (something like Figure 2.5 or Figure 2.6).
- State how the Lorentz Model should be altered to describe a metal and the resulting behavior (Figure 2.7).
- State the mathematical definition and the meaning of the Poynting vector (eq 2.52)
- State the expression for calculating the intensity of an electromagnetic wave from the electric field (eq. 2.62). Explain the relationship between the magnitude of the electric field and the intensity of an electromagnetic wave.

** Second Exam Material **

Student will be able to …

- In terms of optical properties, state the difference between an isotropic material and an anisotropic material. State the physical origin of the anisotropy.
- Express the constitutive relationship for an anisotropic material in which the coordinate system is aligned to the principle axes of the crystal (eq 5.2). Describe how the susceptibility tensor would change if the coordinate system was not aligned with the principle axes.
- For a plane wave, state the significance that k and S are not necessarily parallel in an anisotropic crystal.
- State the relationship between the susceptibility tensor and refractive index (eq 5.18)
- State the meaning of birefringence, biaxial crystal, uniaxial crystal, ordinary index and extraordinary index
- State Snell's law for ordinary and extraordinary polarization (eqns 5.30 and 5.31). State the difference between θ_t and θ' in equation 5.31.
- Describe linear, circular, and elliptical polarization.
- Describe a Jones vector. State the Jones vector presentation for linear polarized light along x, linear polarized light along y, right circularly polarized, and left circularly polarized light. Explain how elliptically polarized light is represented.
- Explain the utility of a Jones matrix. Be able to carry out calculation using Jones matrices (see Example 6.1 for some trivial cases).
- Describe the effect on the direction and magnitude of the electric field when light passes through a polarizer. Describe, from a physical perspective, how a polarizer works.
- Describe the effect of a half-wave plate and a quarter-wave plate on the polarization of a plane wave. In your description, consider different input polarizations (i.e. linear and circular polarizations) and the resulting output. Describe how rotating the wave plate might affect the output polarization
- Sketch a wave packet (see Figure 7.3) and explain the difference between phase velocity and group velocity.
- Write the Fourier Transform and Inverse Fourier transform of an electro-magnetic wave packet (eqn 7.18 and 7.19).
- State the significance of the power spectrum of wave packet.
- Explain qualitatively how Fourier analysis can be used to determine shape of a wave packet propagating through a dispersive medium (eqns 7.31).
- Explain the phenomena of pulse chirping. Use figure 7.10 (sketched from memory) in your explanation.

- Sketch a Michelson interferometer (Figure 8.1) and describe how it works.
- Sketch the output of a Michelson interferometer as a function of mirror position for the following inputs: a monochromatic wave, a pulse (such as Gaussian) of light, and a continuous wave source composed of multiple frequencies.
- Explaining the physical meaning of coherence time and coherence length.
- Sketch a Young's two-slit setup and explain the appearance of a fringe pattern for a point source.
- Describe spatial coherence for an extended source.

** Third Exam Material **

Student will be able to …

- State the relationship between the wave-front of a light wave and the direction of a light ray.
- Explain the meaning of the paraxial approximation and its significance for simplifying the propagation of rays. State Snell's Law using the paraxial approximation (eq 9.39) and the propagation of light (eq 9.27).
- Explain how an ABCD matrix is utilized and how ABCD matrices can be used to explore optical systems.
- Describe Huygens' principle.
- Qualitatively explain the difference between Huygens-Fresnel diffraction formula and the Fresnel-Kirchhoff diffraction formula.
- State the assumptions of the Fresnel approximation and the Fraunhofer approximation.
- Describe the Fraunhofer diffraction pattern of a uniformly illuminated rectangular aperture. State the relationship between the size of the central lobe and the size of the aperture.
- Describe the Fraunhofer diffraction pattern of a uniformly illuminated circular aperture. State the relationship between the size of the central spot and the size of the aperture.
- Describe the role of a lens in seeing a diffraction pattern. State the location of the diffraction pattern with respect to the lens and explain the impact of moving the lens (as well as screen) farther or closer to the aperture.
- Explain the significance of eqn 11.15 when the aperture is a focal length away from the lens.
- State the Rayleigh criterion. Use a picture (similar to Fig 11.8) to explain the meaning. Make sure you can explain the origin of the 1.22 factor in the expression.
- Describe a diffraction grating and how it is used to measure the spectrum of a source.

Applicable Programmatic Student Learning Outcomes

Outcome A: Knowledge and Understanding of the Concepts and Principles of Physics
Upon successful completion this course, students will demonstrate competence solving problems involving the topics listed in the Course Student Learning Outcomes.

Outcome B: Effective Communication
Upon successful completion of this course, students will demonstrate the ability to formulate written solutions to thermodynamic problems and well as explain fundamental concepts of thermodynamics through oral communication.

Meeting & Assessing Student Learning Outcomes:

Outcome A: Knowledge and Understanding of the Concepts and Principles of Physics

Meeting: Students will meet Outcome A by reading the textbook, engaging in lecture, solving weekly assigned pencil-n-paper problems, completing a weekly study-guide, and running simulations in Matlab.

Assessing: Formative assessments will happen throughout the semester. These include feedback in class during discussions and feedback on submitted weekly problem sets. Summative assessments include three in-class exams and the oral final exam.

Outcome B: Effective Communication

Meeting: Students will meet Outcome B by engaging in small group discussions during class time, answering questions posed by the instructor, as well as writing up solutions to problem set questions and study-guide questions.

Assessing: Formative assessments will happen throughout the semester including feedback in class during discussions and feedback on submitted weekly problem sets. Summative assessments include three in-class exams and the oral final exam.

Attendance Policy

Attendance is required and critical to the success of the course. Students are expected to attend all class sessions. If absence is unavoidable, please email the instructor (preferable before the class session).

Evaluation & Grading

45% - Midterm exams (3 × 15% each)
15% - Engagement and participation in lecture
20% - Problem sets
20% - Oral final exam
Total: 100%

A letter grade will be assigned based on performance in the course according to the following scale:

Grade	Quality Points	Percentage Equivalents	Interpretation
A	4.00	93-100	Excellent
A-	3.67	90-92	
B+	3.33	87-89	Superior
B	3.00	83-86	
B-	2.67	80-82	
C+	2.33	77-79	Average
C	2.00	73-76	
C-	1.67	70-72	
D+	1.33	67-69	Below Average
D	1.00	63-66	
D-	0.67	60-62	
F	0	< 60%	Failure

Refer to the Undergraduate Catalog for description of NG (No Grade), W, Z, and other grades.

Exam Make-up Policy:

Student MUST reach out to instructor 24-hours (if possible) prior to missing an exam to discuss alternate plan.

Tentative Course Outline:

Class Meeting	Date	Day	
1	8-30	Tuesday	Chapter 1 – Electromagnetic Phenomena
2	9-1	Thursday	Chapter 1 – Electromagnetic Phenomena
3	9-6	Tuesday	Chapter 2 – Plane Waves and Refractive Index
4	9-8	Thursday	Chapter 2 – Plane Waves and Refractive Index
5	9-13	Tuesday	Chapter 3 – Reflection and Refraction
6	9-15	Thursday	Chapter 3 – Reflection and Refraction
7	9-20	Tuesday	Chapter 4 – Multiple Parallel Interfaces
8	9-22	Thursday	Chapter 4 – Multiple Parallel Interfaces
9	9-27	Tuesday	Review
10	9-29	Thursday	**Exam #1**
11	10-4	Tuesday	Chapter 5 – Propagation in Anisotropic Media
12	10-6	Thursday	Chapter 5 – Propagation in Anisotropic Media
13	10-11	Tuesday	Chapter 6 – Polarization of Light
14	10-13	Thursday	Chapter 6 – Polarization of Light
	10-18	Tuesday	*** Fall Break ***
15	10-20	Thursday	Chapter 6 – Polarization of Light
16	10-25	Tuesday	Chapter 7 – Superposition of Plane Waves
17	10-27	Thursday	Chapter 7 – Superposition of Plane Waves
18	11-1	Tuesday	Chapter 8 – Coherence Theory
19	11-3	Thursday	Chapter 8 – Coherence Theory
20	11-8	Tuesday	Review
21	11-10	Thursday	**Exam #2**
22	11-15	Tuesday	Chapter 9 – Light as Rays
23	11-17	Thursday	Chapter 9 – Light as Rays
24	11-22	Tuesday	Chapter 10 & Chapter 11 – Diffraction
	11-24	Thursday	*** Thanksgiving Break ***
25	11-29	Tuesday	Chapter 10 & Chapter 11 – Diffraction
26	12-1	Thursday	Chapter 10 & Chapter 11 – Diffraction
27	12-6	Tuesday	Review
28	12-8	Thursday	**Exam #3**
	12-13 to 12-16		**Oral final exam during the week**

ACADEMIC & 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.