ELECTROMAGNETIC WAVES AND OPTICS

Instructor: Dr. Romulo Ochoa
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Office Hours: Tuesdays 11:00 a.m. – 2:00 p.m.

Course Description

Properties of electromagnetic waves are studied, with a focus on visible light. Topics include wave motion, interaction of electromagnetic waves with matter, geometrical and physical optics, polarization, optical instruments, holography, laser physics and quantum optics at an intermediate level. Laboratory work involves designing experiments to verify physical models and use of photonics research equipment. The course provides the foundation for imaging, laser physics and optical spectroscopy techniques.

Course Materials

Text: "Optics," Hecht (5th Ed.)
Laboratory Instructions: posted on Canvas

Course Requirements

Class attendance, completion of homework associated with each chapter, completion of lab activities and a formal lab report, lab notebook, presentation, two tests, and a final exam.

Course Goals

1. To provide a foundation in optics necessary for further study in science, engineering and technology.

Learning Objectives:

1.1. Develop an understanding of electromagnetic waves.
1.2. Understand the particle-wave duality of light.
1.3. Apply interference and diffraction of light to various conditions.
1.4. Analyze the effect of indices of refraction to reflection and transmission of light.
1.5. Draw ray diagrams and use them to analyze lens and mirror systems.

2. Students will be able to **solve differential equations** relevant to physical problems.

Learning Objectives:

2.1. Students will set up and solve second order differential equations of a single variable.
2.2. Students will be able to use basic techniques from linear algebra, such as multiplying matrices and finding eigenvectors and eigenfunctions.
2.3. Students will learn to approximate functions using Taylor and Fourier series.

3. Experimental Skills

***Learning Objectives*:**

3.1. Students will learn to write well-defined research questions, develop testable hypotheses, and identify the measurable parameters.
3.2. Students will design an experiment (including setup and procedure) that will measure relevant parameters within appropriate experimental error and considering time, safety, and available equipment.
3.3. Students will troubleshoot experimental issues by creating orderly tests to isolate the problem.
3.4. Students will be able to characterize lenses and mirrors.
3.5. Students will be able to plot data and mathematical functions in Excel. They will effectively display data using appropriate axes, proper labels, legends, and error bars.
3.9. Students will be able to use Excel to perform statistical analyses of experimental data. They will be able to select appropriate fits to data, perform curve fitting, obtain best fit parameters, and explain the significance of the results.

4. To contribute to the development of the student's thinking process through the understanding of the theory and application of this knowledge to the solution of practical problems.

Learning Objectives:

4.1. Identify the important variables in any given physical problem.
4.2. Develop an appropriate strategy for solving physical problems using fundamental principles rather than secondary formulas.
4.3. Successfully apply the appropriate mathematical methods to implement your solution.
4.4. Evaluate your solutions to determine if they are physically reasonable.
4.5. Develop spatial reasoning in three dimensions.

5. To engage in productive communication and collaboration with peers.

Learning Objectives:

5.1. Contribute productively to group discussions about physical phenomena and problems.
5.2. Clearly articulate their ideas about how the natural world behaves.
5.3. Use scientific reasoning and argumentation to defend their ideas against competing ideas.
5.4. Explain physical phenomena and mechanisms using both formal and informal language, as well as graphical, pictorial, mathematical, or other representations.

II. Course Outline

1. Geometrical optics.- (Ch. 5)
   Lenses. Mirrors. Prisms. Fiberoptics. Aberrations.
   Homework problems: 12, 13, 14, 20, 31, 37, 43, 46, 48, 72, 73, 78, 84, 86, A1, A2, A3, A4, A5, A16, A7.

2. Wave motion.- (Ch. 2)

One-dimensional waves. Harmonic waves. Phase and phase velocity. The superposition principle. The complex representation. Plane waves. Three-dimensional waves.
Homework problems: 21, 22, 28, 37, 39, 42, 43, 52, A8, A9, A10.

3. Electromagnetic theory, photons and light.- (Ch. 3)

Basic laws of electromagnetic theory. Electromagnetic waves. Energy and momentum. Radiation. Light and matter. The electromagnetic-photon spectrum.
Homework problems: 2, 5, 8, 23, 24, 25, 26, 32, 39, 40, 45, 55.

4. The propagation of light.- (Ch. 4)

Rayleigh scattering. Reflection. Refraction. Fermat's principle. The electromagnetic approach. Total internal reflection. Optical properties of metals.
Homework problems: 4, 6, 7, 15, 16, 17, 23, 28, 29, 42, 87, A11.

Test 1 (TBA)

5. Superposition of waves.- (Ch. 7)

Addition of waves of the same frequency. Standing waves. The addition of waves of different frequency. Beats. Group velocity. Fourier analysis of anharmonic waves. Fourier integrals of nonperiodic waves. Pulses and wavepackets. Coherence length. Fourier Optics.
Homework problems: 5, 6, 10, 15, 16, 21, 22, 38, 39, 61, A12.

6. Polarization.- (Ch. 8)

Polarized light. Polarizers. Dichroism. Birefringence. Scattering and polarization. Polarization by reflection. Retarders. Circular polarizers. Optical activity. A mathematical description of polarization.
Homework problems: 4, 7, 8, 15, 16, 25, 27, 30, 43, 47, 95, A13, A14, A15.

Test 2 (TBA)

7. Interference.- (Ch. 9)

Conditions for interference. Interferometers. Multiple-beam interference.
Homework problems: 6, 9, 11, 12, 13, 22, 34, 47, 50.

8. Diffraction.- (Ch. 10)

Fraunhofer diffraction. Fresnel diffraction. The diffraction grating.
Homework problems: 8, 9, 51, 53, 55, 56, 61.

9. Modern optics: lasers and other topics

Fourier optics. Lasers and laser light. Raman Effect. Imagery - the spatial distribution of optical information. Holography.

Final Exam (TBA)

III. Laboratory

Lab. 1. Snell's Law.
Lab. 2. Geometrical Optics I
Lab. 3. Geometrical Optics II
Lab. 4. Microwaves Optics.
Lab. 5. Interferometers. Mirrored and multiple beam.
Lab. 6. Reflectance Curves.
Lab. 7 Polarization I. Malus's Law. Optical Activity.
Lab. 8. Discussion of Advanced topics in photonics
Lab. 9. Diffraction: Multiple slits, circular slits, and gratings.
Lab. 10. Fiber Optics
Lab. 11. Holography I. Single beam reflection holograms.
Lab. 12. Holography II. Single beam transmission holograms.

IV. Assessment of Student Performance

1. tests (30 points)
2. final exam (30 points)
3. homework problems (10 points)
4. lab. grade (20 points)
5. Presentation of advanced topics in photonics (10 points)

For the laboratory grade students must prepare one formal report, have at all times in lab a lab notebook in which they must write all calculations, observations and procedures performed during the experiments. Students are expected to be in the lab on time, points will be deducted for tardiness. The lab report represent 2 points towards your final grade, lab participation and performance are 16 points, and the lab notebook is 2 points.

Homework is due one week after the corresponding chapter has been completed in the lectures unless otherwise noted. Late homework will not be accepted.

Grading Scale	
Final Score	Letter Grade
92.5 - 100	A
89.5 – 92.4	A-
86.5 – 89.4	B+
82.5 – 86.4	B
79.5 – 82.4	B-
76.5 – 79.4	C+
72.5 – 76.4	C
69.5 – 72.4	C-
66.5 – 69.4	D+
59.5 – 66.4	D
0 – 59.4	F

Exam or Test Absences Policy

I. **Final Exam**: The final exam schedule is known well in advance. Serious personal illness and death in immediate family will be the only acceptable excuses. All

students must follow the general guidelines stated below. All excused students must take their make-up final exam before 2:00 PM on the last day of the final exams, or they will receive an incomplete (I) or an F. It is the student's responsibility to request the make-up and provide a timely and acceptable proof.

II. Tests: You should make every effort to take the test at its scheduled date. If you cannot:
You must **inform** the instructor about the nature of your absence before the missed test (for non-emergency absences) or within 24 hours after the missed test (for emergency absences);
By the following class period you must show the instructor (or arrange to be shown) a **proof** that the absence is excusable**;** it is the student's responsibility to contact the instructor in a timely manner and provide an acceptable excuse.

III. Excuses:
Non-acceptable: Travel plans, weddings, lack of preparation, busy schedules; too many other obligations, assignments, or tests; job interviews, doctor's appointments or any other engagements or appointments that can be scheduled at different times, and alike, **will not be accepted** and the student will receive zero points for the test - **no exceptions**. The test dates are known ahead of time, so please plan accordingly.
Acceptable: Personal illness, death in one's family, and alike.

IV. Taking the Make-Up:
A student will be allowed to take a make-up only for an excused absence;
Unless otherwise stated in writing by her/his physician, s/he must take the make-up **within seven days** of the missed examination.
If the student fails to inform the instructor, does not provide an acceptable proof, or does not take the make-up in a timely manner, s/he will be given zero.
The make-ups will be **different** from regular examination, so **timely notification** of the instructor is essential.

Fourth Hour:

In this class, the deep learning outcomes associated with TCNJ's 4th hour are accomplished by a series of rigorous educational assignments that extend beyond the typical scheduled class time. These include activities conducted in the scheduled laboratory section, out-of-class problem sets, and out-of-class online learning activities such as video lectures and reading assignments.

Additional Resources

Guenther, R., Modern Optics, J. Wiley & Sons, 1990.
Halliday, Resnick and Walker, Fundamentals of Physics,10th Ed.,Wiley & Sons, 2017.
Hecht, E., Optics, Shaum's Outline Series, McGraw-Hill, 1975.
Klein, M.V. and Furtak, T.E. Optics, 2nd Ed., J. Wiley & Sons, 1986.
Pedrotti, F. L., Pedrotti, L. S., and Pedrotti, L. M., Introduction to Optics, 3rd Ed., Pearson-Prentice Hall, 2007.
Young and Freedman, University Physics 14th Ed., New York, Pearson, 2016.

SELECTED TCNJ POLICIES

Final Examinations

The final exam is not scheduled until the middle of the semester. Therefore do not plan on any travel until after the last day of the exam period. TCNJ's final examination policy is available on the web:

http://policies.tcnj.edu/policies/digest.php?docId=9396

Attendance

Every student is expected to participate in each of his/her courses through regular attendance at all class sessions. It is further expected that every student will be present, on time, and prepared to participate when scheduled class sessions begin. While attendance itself is not used as a criterion for academic evaluations, grading in this course is based on participation in quizzes to be given at the beginning of several classes. No make-ups or extensions will be given unless a student has a genuine emergency. If a student misses an exam or assignment deadline they must contact the instructor within 36 hours to explain the situation; otherwise the student will earn a zero for that exam or assignment.
Students who must miss classes due to participation in a field trip, athletic event, or other official college function or for a religious holiday should arrange with their instructors for such class absences well in advance. In every instance, however, the student has the responsibility to initiate arrangements for make-up work.

TCNJ's full attendance policy *is available at:*
http://policies.tcnj.edu/policies/digest.php?docId=9134

Academic Integrity Policy

Academic dishonesty is any attempt by the student to gain academic advantage through dishonest means, to submit, as his or her own, work which has not been done by him/her or to give improper aid to another student in the completion of an assignment. Such dishonesty would include, but is not limited to: submitting as his/her own a project, paper, problem set, report, test, or speech copied from, partially copied, or paraphrased from the work of another (whether the source is printed, under copyright, or in manuscript form). Credit must be given for words quoted or paraphrased. The rules apply to any academic dishonesty, whether the work is graded or ungraded, group or individual, written or oral.
TCNJ's academic integrity policy *is available at:*
http://policies.tcnj.edu/policies/digest.php?docId=9394

Americans with Disabilities Act (ADA) Policy

Any student who has a documented disability and is in need of academic accommodations should notify the professor of this course and contact the Office of Differing Abilities Services (609-771-2571). Accommodations are individualized and in accordance with Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1992. *TCNJ's Americans with Disabilities Act (ADA) policy is available at:*
http://affirm.pages.tcnj.edu/files/2011/08/Americans-with-Disabilities-Act-4.7.10.docx