

PHYSICS 340: OPTICS

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Office hours: Tuesday, Thursday, 9:00-11:00
Meeting times: MWF 11:10; Youngchild 115
Textbook: *Optics*, Fourth Edition, E. Hecht, Addison-Wesley (2002)

COURSE OBJECTIVES:

1. This course will provide you with a background in the subject of physical optics; the study of properties of light understood as a propagating electromagnetic wave.
2. Investigate the origins of the phenomena of reflection and refraction and explore the microscopic origins of the dielectric constant and the index of refraction.
3. Explore the relation between ray and wave optics and understand the properties of optical elements: lenses, mirrors, stops, fiber optics.
4. Study the interaction between light and matter and explore polarization dependent phenomena.
5. Use the wave theory to explain the phenomena of interference and diffraction in the Fresnel and Fraunhofer limits.
6. Introduce the Fourier Transform for analyzing optical problems.
7. Independently explore an advanced topic in optics.

COURSE ELEMENTS:

1. The textbook is a readable, complete exposition of the subject of optics. There is little need to look at other optics texts except when pursuing advanced topics. The major problem with the text is an excess of detail and applications. The reading assignments are long but I will give guidance in class concerning the sections that are most important. Hecht is concerned with making connections between classical and quantum views of light and includes sections such as "QED and the Lens" in chapter 5. These sections provide interesting reading but are not central to the objectives of this course. You can consider all such sections optional reading.
2. Homework: Four to five problems will be assigned each day and will be collected as we complete discussions of the chapter in which they are contained. A selection of the problems will be graded, but not all. Problems not graded will be checked as present or absent. Solutions need to be neatly

recorded and provide complete explanations to receive full credit. Steps that are purely algebraic need not be explained, but all other physical reasoning should be documented. Your objective is to write a solution that provides a compelling, complete explanation that can be easily understood by a classmate having difficulty with the problem.

3. Class Presentations: Working with a partner, you will construct a demonstration that illustrates reflection, refraction, interference, or diffraction..
4. Hour Exams: Two one-hour exams will be given.
5. Advanced Topic Presentation: During the last 2 weeks of the course you will prepare a short paper (4-5 pages) and presentation on an advanced topic of your choosing. The topic may involve optics only or may involve the use of optics in probing some physical system. During the last week of the course you will give a 15-minute presentation to the class on your topic. I will meet with each of you to approve your choice of topic and also suggest potential references.
6. Final Examination: The final examination will be comprehensive.

GRADING:

One-hour exams (total)	30%
Homework & Class Problem Presentation	15%
Demonstration	5%
Advanced project	10%
Final Exam	40%

HONOR SYSTEM:

The Honor Code applies to all work submitted for credit in this course. This includes graded problem assignments, your advanced project, and exams. At the end of each assignment you will be asked to reaffirm the Lawrence University Honor Code. Collaboration and discussion of problems is encouraged on all assignments as long as such discussions are explicitly acknowledged in the submitted work. Acknowledgment of discussions is required only if a key insight into the problem was obtained through the discussion. I expect that each of you will independently write up your solutions.

TENTATIVE LECTURE PLAN

MONDAY	WEDNESDAY	FRIDAY
	January 4 1 Introduction, Complex Solutions to Wave Eq Chapt.1, Chapt 2.1-2.5	January 6 2 Wave properties & Calculations Chapt. 2.6-2.10, 3.1
Jan. 9 3 EM Waves Chapt 3.2-3.4 Chapter 2 Problems Due	Jan. 11 4 EM waves in dielectrics; dispersion Chapt. 3.5-3.6, 4.1-4.2	Jan. 13 5 Reflection and Refraction Chapt 4.3-4.6. Chapter 3 Problems Due
Jan. 16 MLK Day No Class	Jan. 18 6 Total Reflection & Absorption Chapt 4.7-4.10	Jan. 20 7 Thin Lenses Chapt. 5.1-5.2 Chapter 4 Problems Due
Jan 23 8 Lenses, Mirrors, Stops Chapt. 5.3-5.4	Jan. 25 9 Prisms, Fiberoptics, Optical Systems Chapt. 5.5-5.	Jan. 27 10 Optical Systems Presentations
Jan. 30 11 Aberrations Chapt. 6.3 Chapter 5 Problems Due	Feb. 1 12 HOURLY EXAM	Feb. 3 13 Wave Superposition & Standing Waves: Chapt 7.1-7.2
Feb. 6 14 Fourier Analysis & Wave Packets Chapt. 7.3-7.4	Feb. 8 15 Polarization and Birefringence Chapt 8.1-8.4 Chapter 7 Problems Due	Reading Period
Feb. 13 16 Polarization Effects Chapt 8.5-8.9	Feb. 15 17 Optical Activity & Mathematical Description of Polarization Chapt. 8.10-8.13	Feb. 17 18 Interference 9.1-9.3 Chapter 8 Problems Due
Feb. 20 19 Interferometers Chapt 9.4-9.6	Feb. 22 20 Thin Films Chapt. 9.7-9.8	Feb. 24 21 Fraunhofer Diffraction Chapt. 10.1-10.2 Chapter 9 Problems Due
Feb. 27 22 Fraunhofer Diffraction	Mar. 1 23 HOURLY EXAM	Mar. 3 24 Fresnel Diffraction Chapt. 10.3
Mar. 6 25 Fourier Optics Chapt. 11.1-11.3 Chapter 10 Problems Due	Mar. 8 26 Fourier Optics Project Presentations	Mar. 10 27 Project Presentations Chapter 11 Problems Due

PHYSICS 34 PROBLEM ASSIGNMENTS

Lecture	
2	Chapter 2: 16,22,35,40,44
3	Chapter 3: 1,10,25,31,38,48
4	Chapter 4: 4,5,21
5	Chapter 4: 55,63,70,72,73
6	Chapter 4: 78 + supplemental problems
7	Chapter 5: 5,7,31,38,39
8	Chapter 5: 58,84,87
9	
10	
11	Chapter 6: 27, 28
12	EXAM
13	Chapter 7: 2,4,6,7,9
14	Chapter 7: 18,21,30,35,39, 42, 43
15	Chapter 8: 1,3,7,13,28,32,35
16	Chapter 8: 43,48,66
17	
18	Chapter 9: 1,5,11,15
19	Chapter 9: 28,32,36,37,40,41,43
20	
21	Chapter 10: 3,8,13,23,25
22	Chapter 10: 26,41
23	EXAM
24	Chapter 10: 52
25	
26	Chapter 11: 10,11,12,30
27	

FINAL EXAM: Tuesday, March 14, 8:30 AM, Y-115

Chapter 4 Supplemental Problems

1. Determine the properties of electromagnetic waves in a conductor. Here current cannot be neglected so Ampere's Law becomes.

$$\vec{\nabla}_x \left(\frac{\vec{B}}{\mu} \right) = \vec{J} + \varepsilon \frac{\partial \vec{E}}{\partial t}, \text{ where Ohm's Law implies that } \vec{J} = \sigma \vec{E}.$$

The wave equation for the electric field becomes

$$\nabla^2 \vec{E} = \mu \varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} + \mu \sigma \frac{\partial \vec{E}}{\partial t}.$$

- a.) Assuming a solution of the form $\vec{E} = \vec{E}_0 e^{i(kx - \omega t)}$ with k allowed to be complex, show that

$$k^2 = \omega^2 \mu \varepsilon \left[1 + \frac{i\sigma}{\omega \varepsilon} \right].$$

- b.) In a good conductor $\sigma \gg \omega \varepsilon$. Find k in this limit and show that the skin depth is given by

$$\delta = \frac{1}{\alpha} = \frac{1}{\sqrt{2\omega\mu\sigma}}, \text{ where the irradiance of the wave at depth } x \text{ is given by } I = I_0 e^{-\alpha x}, \text{ where}$$

I_0 is the irradiance at $x = 0$.

- c.) What thickness of aluminum is needed on a glass surface to make a mirror that is 50% transmitting for red light of wavelength of 630 nm? For aluminum the magnetic permeability is just that of free space and the conductivity is $3.77 \times 10^7 \text{ s}^{-1} \text{m}^{-1}$.

2. Write down the equations that describe the components of the real electric field. Describe the electric field and the direction of propagation of each wave.

a.) $E_0 (\hat{x} - i\hat{y}) e^{i(kz - \omega t)}$

b.) $\frac{E_0}{\sqrt{2}} \hat{x} (1 + i) e^{i(kz - \omega t)}$