Syllabus for ‘Optics’

I. Basic Information

Title	Optics	**Course #**	PHYS3126
Category	Major Basic	**Audience**	Physics (normal) - International class
Credits	3	**Hours**	51
Instructor	LUO, Jie (罗杰)	**Revised**	Jun. 5, 2023
Textbook	“Optics” by Eugene Hecht, 4th edition		

II. Goals and Objectives

A. Overall goals

This course provides an introduction to optical science with elementary engineering applications. Topics covered in geometrical optics include: reflection and refraction, lens, mirrors, ray-tracing, lens design. Topics covered in wave optics include: basic electrodynamics, polarization, interference, Fresnel and Fraunhofer diffraction, image formation, resolution. Analytical and numerical tools used in optical design are emphasized. The prerequisite course include: “General Physics” and “Electricity and Magnetism”

Through this course, the students should 1) learn the understanding of the nature of light; 2) learn the basic laws of geometrical optics and optical imaging of lens; 3) learn the basic laws of scaler wave optics, including interference, diffraction and polarization.

B. Objectives

Objective 1： In the chapters relating to the topics such as the history of optics of Chinese scientists and engineers of the older generation in developing the technologies will be shared. Their great efforts, devotions, and perseverance will stimulate the students’ enthusiasm for learning science and encourage them to serve our country.

Objective 2： Optics is the course that provides an introduction to optical science with elementary engineering applications. The students should not only learn the basic concepts of optics and the mathematic tools, but also learn to build physical intuition. Such trainings set up a foundation for their future study and research.

Objective 3： Show examples that are closely related to daily life, such as rainbows, blue sky, color, such that the students can learn how to use the knowledge of optics to solve practical problems. Show examples that are closely related to the research topics in optics, such as metamaterials, metasurfaces, negative refraction, zero refractive index, cloaking, so as to improve the students' learning interests. Moreover, the students can learn how to employ the knowledge of optics to solve frontier issues in optics. The students are also encouraged learn how to use the finite-element software COMSOL Multiphysics to simulation the optical phenomena.

Objective 4: To develop the habit of self-education, the students are asked to preview the context before class and moreover study the chapters of "Fourier Optics" and "Modern Optics" by themselves. All-English teaching would improve their ability in communicating internationally and reading the scientific materials in English.

C. Correlations—Objectives, graduation requirements, teaching contents

Table 1: Correlations between course objectives, graduation requirements and teaching contents

Objectives	**Teaching contents**	**Graduation requirements**
Objective 1	Contents of all chapters. Examples include: Chapter 0 Introduction (Cloaking by Chinese scientists like Prof. Yun Lai and Hongsheng Chen); Chapter 4 Diffraction (Five-hundred-meter Aperture Spherical radio Telescope in Guizhou)	Requirements 1, 3
Objective 2	Contents of All chapters. Examples including: Chapter 2 The propagation of light (Mathematical description of travelling waves); Chapter 3 Interference (Mathematical description of different kinds of interferometers); Chapter 4 Diffraction (Mathematical description of Frauenhofer diffractions for slits/aperture); Chapter 5 Polarization (Mathematical description and intuitive understanding of different kinds of polarizations)	Requirements 2, 6
Objective 3	Contents of All chapters. Examples including: rainbows, blue sky, color, metamaterials, metasurfaces, negative refraction, zero refractive index, cloaking. The finite-element software COMSOL Multiphysics will be briefly introduced.	Requirements 3, 4, 7
Objective 4	Contents of All chapters in which "Fourier Optics" and "Modern Optics" are for self-taught.	Requirements 5, 6, 8

III. Teaching Contents

Chapter 0 Introduction

1. Teaching objectives

To learn the history of optics, some basic aspects of geometrical optics, scaler wave optics and the nature of light

2. Focus and/or Difficulties

The understanding of particle-wave duality; The difference and relationship between geometrical optics and scaler wave optics

3. Teaching contents

The history of physics; the nature of light; Newton’s particle hypothesis; Huygens’ wave hypothesis; Maxwell electromagnetic theory; photoelectric effect; the concept of photons; particle-wave duality

4. Teaching method

Lecture PPT presentation; Heuristic question; Interaction with students

5. Evaluations

Homework, quiz and examinations

Chapter 1 Geometrical optics

1. Teaching objectives

To learn the basic law of geometric optics—Fermat’s principle, and how to use apple Fermat’s principle to derive the laws of reflection and refraction, as well as the rule of paraxial image formation by thin lens

2. Focus and/or Difficulties

The understanding of the nature of Fermat’s principle; The relationship with wave optics; Frustrated total internal reflection; Paraxial image formation of different kinds of lens

3. Teaching contents

Fermat’s principle; Law of reflection; Law of refraction; Total internal reflection; Frustrated total internal reflection; Negative refraction; Image properties; Refraction at a single spherical surface; Spherical lens; General thin lens equation; Imaging by a converging lens; Imaging by a diverging lens; Mirrors

4. Teaching method

Lecture PPT presentation; Heuristic question; Interaction with students

5. Evaluations

Homework, quiz and examinations

Chapter 2 The propagation of light

1. Teaching objectives

To learn the basic properties of classical waves, electromagnetic waves and light waves; To learn how light propagates in terms of waves

2. Focus and/or Difficulties

The relationship between different quantities of waves; The understanding of light propagation in terms of wave scattering and Huygens's principle

3. Teaching contents

Basic properties of classical waves; Mathematical description of travelling waves; The wave equation; The superposition of waves; Electromagnetic waves and light; Propagation of light in terms of waves; Scattering and interference of light; The propagation of light; Dispersion; Huygens's principle; Revisit of reflection and refraction in terms of wave optics

4. Teaching method

Lecture PPT presentation; Heuristic question; Interaction with students

5. Evaluations

Homework, quiz and examinations

Chapter 3 Interference

1. Teaching objectives

To learn the concepts of light interference, as well as the mathematical description of wavefront-splitting interference and amplitude-splitting interference, and their physical understanding

2. Focus and/or Difficulties

Mathematical description of different kinds of interferometers; The approximation applied in the mathematical derivations; The understanding of half-wave loss

3. Teaching contents

General considerations of wave interference; Condition of interference; Young's experiment: Double-slit interference; Understanding of Young's experiment in terms of particle-wave duality; Amplitude-splitting interferometers; Dielectric films—double-beam interference; Fringes of equal inclination; Fringes of equal thickness; Newton's ring; Antireflection coating; The understanding of half-wave loss; Michelson interferometer; Mach-Zehnder interferometer; Multiple-beam interference; Fabry-Perot interferometer; Rotating Sagnac interferometer

4. Teaching method

Lecture PPT presentation; Heuristic question; Interaction with students

5. Evaluations

Homework, quiz and examinations

Chapter 4 Diffraction

1. Teaching objectives

To learn the concepts of light diffraction, as well as the mathematical description of Frauenhofer interference for slits/aperture; To learn the limitation of imaging systems caused by diffraction; To learn the basic concepts of Fresnel diffraction

2. Focus and/or Difficulties

Mathematical description of Frauenhofer diffractions for slits/aperture; The difference and relationship between light interference and diffraction; The understanding of Fresnel zone plates; The understanding of the limitation of imaging systems caused by diffraction

3. Teaching contents

General considerations of diffraction; The Huygens–Fresnel principle; Frauenhofer (far-field) and Fresnel (near-field) diffraction; Fraunhofer diffraction — The single-slit diffraction; The double-slit diffraction; Multi-slit diffraction; Conditions of principal maxima, minima, subsidiary maxima; Diffraction grating; Grating equation; Resolving power; X-ray diffraction; The Rectangular aperture diffraction; The circular aperture diffraction; Resolution of imaging systems; Nondiffracting beam; Fresnel Diffraction; Circular aperture/obstacle; Fresnel zone plates; The vibration curve; Cornu spiral; Babinet’s Principle

4. Teaching method

Lecture PPT presentation; Heuristic question; Interaction with students

5. Evaluations

Homework, quiz and examinations

Chapter 5 Polarization

1. Teaching objectives

To learn mathematical description and intuitive understanding of different kinds of polarizations; To learn the polarization properties in light scattering and reflection; To learn the light propagation in birefringent crystals and their applications in controlling light polarization

2. Focus and/or Difficulties

Mathematical description and intuitive understanding of different kinds of polarizations; The understanding of concepts of birefringent crystals; The difference and relationship between o-ray and e-ray; The mechanism and functionalities of different kinds of birefringent polarizers

3. Teaching contents

The Nature of polarized light; Linear polarization; Circular polarization; Elliptical polarization; Natural light; Polarizers; Malus’s law; Scattering and polarization; Polarization by reflection; Brewster's law; Birefringent crystal; Birefringence; o-ray and e-ray; Birefringent Polarizers; Full-, half-, quarter- wave plates; Circular polarizers; Optical activity; Chirality and circular birefringence; The Faraday, Kerr and Pockels effects

4. Teaching method

Lecture PPT presentation; Heuristic question; Interaction with students

5. Evaluations

Homework, quiz and examinations

IV. Teaching Hours

Table 2: Chapters and teaching hours

Chapters	Contents	Hours
Chapter 0	Introduction	1
Chapter 1	Geometrical optics	5
Chapter 2	The propagation of light	6
Chapter 3	Interference	12
Chapter 4	Diffraction	15
Chapter 5	Polarization	12

V. Teaching Schedule

Table 3: Schedule

Week	Chapter	Contents	hours	Assignments	Note
1	Chapters 0 and 1	Introduction and Geometrical optics	3	Homework: Selected problems	
2	Chapter 1	Geometrical optics	3	Homework: Selected problems	
3	Chapter 2	The propagation of	3	Homework: Selected problems	

		light			
4	Chapter 2	The propagation of light	3	Homework: Selected problems	
5	Chapter 3	Interference	3	Homework: Selected problems	
6	Chapter 3	Interference	3	Homework: Selected problems	
7	Chapter 3	Interference	3	Homework: Selected problems	
8	Chapter 3	Interference	3	Homework: Selected problems	
9	Chapter 4	Diffraction	3	Homework: Selected problems	
10	Chapter 4	Diffraction	3	Homework: Selected problems	
11	Chapter 4	Diffraction	3	Homework: Selected problems	
12	Chapter 4	Diffraction	3	Homework: Selected problems	
13	Chapter 4	Diffraction	3	Homework: Selected problems	
14	Chapter 5	Gravitation	3	Homework: Selected problems	
15	Chapter 5	Polarization	3	Homework: Selected problems	
16	Chapter 5	Polarization	3	Homework: Selected problems	
17	Chapter 5	Polarization	3	None	

VI. References

1. “Introduction to Optics” by Frank L Pedrotti, Leno M Pedrotti, Leno S Pedrotti

2. “Optics” by Ajoy Ghatak, 4th edition.

3. 《光学教程》第四版 姚启钧著

VII. Teaching method

1. Lecture: PPT plus writing on the blackboard. Outlines, examples, schematic pictures and cartoon or movies are shown by PPT while derivations and solutions are performed on the blackboard. Examples are selected from the above listed reference books.
2. Preview: All students are asked to preview the context before class.
3. Self-education: Students need to study “Fourier Optics” and “Modern Optics” by themselves.

VIII. Assessment and Grading

A. Correlations between assessment and course objectives

Table 4: Correlations between assessment and course objectives

Objectives	Assessment points	Way of assessment
Objective 1	All teaching contents	Performance + Quiz + Midterm Exam + Final Exam
Objective 2	All teaching contents	Performance + Quiz + Midterm Exam + Final Exam
Objective 3	All teaching contents	Performance + Quiz + Midterm Exam + Final Exam
Objective 4	All teaching contents	Performance + Quiz + Midterm Exam + Final Exam

B. Grading

1. Grading Scheme

Performance 10% (including question answering 5%, homework 5%); Three quizzes 45%; Midterm exam 20%; Final exam 25%.

2. Percentages in the assessment and Degrees of accomplishment of the objectives

Table 5: Percentages in the assessment and Degrees of accomplishment of the objectives

Percentages	Performance	Quiz (3)	Midterm	Final exam	Degree of

Objectives	and homework		exam		accomplishment
Objective 1	10%	45%	20%	25%	Performance + Homework + Quiz + Midterm Exam + Final Exam
Objective 2					
Objective 3					
Objective 4					

C. Standards

Objectives	Standards				
	90-100	**80-89**	**70-79**	**60-69**	**＜60**
	优	良	中	合格	不合格
	A	**B**	**C**	**D**	**F**
Objective 1	Performance + Homework + Quiz + Midterm Exam + Final Exam				
Objective 2					
Objective 3					
Objective 4					