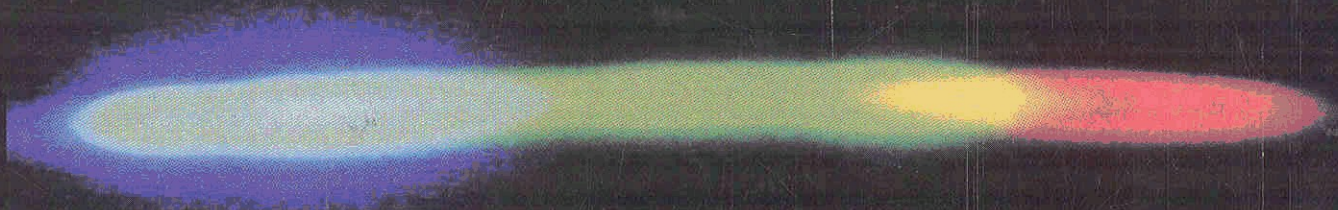


The McGraw-Hill Companies

OPTICS

4th
EDITION



AJOY GHATAK

CONTENTS

Preface

v

1. History of Optics

1.1

References 1.15

2. What is Light?

2.1

2.1 Introduction 2.1

2.2 The Corpuscular Model 2.1

2.3 The Wave Model 2.3

2.4 The Particle Nature of Radiation 2.5

2.5 Wave Nature of Matter 2.6

2.6 The Uncertainty Principle 2.7

2.7 The Single Slit Diffraction Experiment 2.8

2.8 The Probabilistic Interpretation of Matter Waves 2.9

2.9 An Understanding of Interference Experiments 2.10

2.10 The Polarization of a Photon 2.12

2.11 The Time-energy Uncertainty Relation 2.14

Summary 2.14

Problems 2.15

Solutions 2.15

References and Suggested Readings 2.16

Part 1 Geometrical Optics

3. Fermat's Principle and Its Applications

3.3

3.1 Introduction 3.3

3.2 Laws of Reflection and Refraction from Fermat's Principle 3.4

3.3 Ray Paths in an Inhomogeneous Medium 3.8

3.4 The Ray Equation and its Solutions 3.12

3.5 Refraction of Rays at the Interface between an Isotropic Medium and an Anisotropic Medium 3.18

Summary 3.21

Problems 3.21

References and Suggested Readings 3.24

4. Refraction and Reflection by Spherical Surfaces

4.1

4.1 Introduction 4.1

4.2 Refraction at a Single Spherical Surface 4.2

4.3 Reflection by a Single Spherical Surface 4.3

4.4 The Thin Lens 4.4

4.5 The Principal FOCI and Focal Lengths of a Lens 4.5

4.6 The Newton Formula 4.7

4.7 Lateral Magnification 4.7

4.8 Aplanatic Points of a Sphere 4.8

- 4.9 The Cartesian Oval 4.10
- 4.10 Geometrical Proof for the Existence of Aplanatic Points 4.10
- 4.11 The Sine Condition 4.11
 - Summary 4.13
 - Problems 4.13
 - References and Suggested Readings 4.14

5. The Matrix Method in Paraxial Optics 5.1

- 5.1 Introduction 5.1
- 5.2 The Matrix Method 5.2
- 5.3 Unit Planes 5.7
- 5.4 Nodal Planes 5.8
- 5.5 A System of Two Thin Lenses 5.9
 - Summary 5.11
 - Problems 5.11
 - References and Suggested Readings 5.12

6. Aberrations 6.1

- 6.1 Introduction 6.1
- 6.2 Chromatic Aberration 6.1
- 6.3 Monochromatic Aberrations 6.4
 - Summary 6.12
 - Problems 6.12
 - References and Suggested Readings 6.13

Part 2 Vibrations and Waves

7. Simple Harmonic Motion, Forced Vibrations and Origin of Refractive Index 7.3

- 7.1 Introduction 7.3
- 7.2 Simple Harmonic Motion 7.3
- 7.3 Damped Simple Harmonic Motion 7.7
- 7.4 Forced Vibrations 7.9
- 7.5 Origin of Refractive Index 7.11
- 7.6 Rayleigh Scattering 7.15
 - Summary 7.16
 - Problems 7.16
 - References and Suggested Readings 7.18

8. Fourier Series and Applications 8.1

- 8.1 Introduction 8.1
- 8.2 Transverse Vibrations of a Plucked String 8.3
- 8.3 Application of Fourier Series in Forced Vibrations 8.5
- 8.4 The Fourier Integral 8.6
 - Summary 8.7
 - Problems 8.8
 - References and Suggested Readings 8.8

9. The Dirac Delta Function and Fourier Transforms 9.1

- 9.1 Introduction 9.1
- 9.2 Representations of the Dirac Delta Function 9.1
- 9.3 Integral Representation of the Delta Function 9.2
- 9.4 Delta Function as a Distribution 9.2
- 9.5 Fourier Integral Theorem 9.3
- 9.6 The Two and Three Dimensional Fourier Transform 9.5
 - Summary 9.6
 - Problems 9.6

10. Group Velocity and Pulse Dispersion	10.1
10.1 Introduction 10.1	
10.2 Group Velocity 10.1	
10.3 Group Velocity of a Wave Packet 10.5	
10.4 Self Phase Modulation 10.11	
<i>Summary</i> 10.13	
<i>Problems</i> 10.14	
<i>References and Suggested Readings</i> 10.15	
11. Wave Propagation and the Wave Equation	11.1
11.1 Introduction 11.1	
11.2 Sinusoidal Waves: Concept of Frequency and Wavelength 11.3	
11.3 Types of Waves 11.4	
11.4 Energy Transport in Wave Motion 11.4	
11.5 The One-dimensional Wave Equation 11.5	
11.6 Transverse Vibrations of a Stretched String 11.6	
11.7 Longitudinal Sound Waves in a Solid 11.7	
11.8 Longitudinal Waves in a Gas 11.8	
11.9 The General Solution of the One-dimensional Wave Equation 11.9	
<i>Summary</i> 11.13	
<i>Problems</i> 11.13	
<i>References and Suggested Readings</i> 11.14	
12. Huygens' Principle and Its Applications	12.1
12.1 Introduction 12.1	
12.2 Huygens' Theory 12.1	
12.3 Rectilinear Propagation 12.2	
12.4 Application of Huygens' Principle to Study Refraction and Reflection 12.3	
12.5 Huygens' Principle in Inhomogeneous Media 12.9	
<i>Summary</i> 12.9	
<i>Problems</i> 12.10	
<i>References and Suggested Readings</i> 12.10	

Part 3 Interference

13. Superposition of Waves	13.3
13.1 Introduction 13.3	
13.2 Stationary Waves on a String 13.3	
13.3 Stationary Waves on a String Whose Ends are Fixed 13.5	
13.4 Stationary Light Waves: Ives and Wiener's Experiments 13.6	
13.5 Superposition of Two Sinusoidal Waves 13.6	
13.6 The Graphical Method for Studying Superposition of Sinusoidal Waves 13.7	
13.7 The Complex Representation 13.9	
<i>Summary</i> 13.9	
<i>Problems</i> 13.9	
<i>References and Suggested Readings</i> 13.10	
14. Two Beam Interference by Division of Wavefront	14.1
14.1 Introduction 14.1	
14.2 Interference Pattern Produced on the Surface of Water 14.2	
14.3 Coherence 14.5	
14.4 Interference of Light Waves 14.6	
14.5 The Interference Pattern 14.7	
14.6 The Intensity Distribution 14.8	
14.7 Fresnel's Two-mirror Arrangement 14.13	
14.8 Fresnel Biprism 14.14	
14.9 Interference with White Light 14.15	

14.10	Displacement of Fringes	14.15	
14.11	The Lloyd's Mirror Arrangement	14.16	
14.12	Phase Change on Reflection	14.16	
	<i>Summary</i>	14.17	
	<i>Problems</i>	14.17	
	<i>References and Suggested Readings</i>	14.18	
15.	Interference by Division of Amplitude		15.1
15.1	Introduction	15.1	
15.2	Interference by a Plane Parallel Film when Illuminated by a Plane Wave	15.2	
15.3	The Cosine Law	15.3	
15.4	Non-reflecting Films	15.4	
15.5	High Reflectivity by Thin Film Deposition	15.7	
15.6	Reflection by a Periodic Structure	15.8	
15.7	Interference by a Plane Parallel Film when Illuminated by a Point Source	15.12	
15.8	Interference by a Film with Two Non-parallel Reflecting Surfaces	15.14	
15.9	Colours of Thin Films	15.17	
15.10	Newton's Rings	15.18	
15.11	The Michelson Interferometer	15.22	
	<i>Summary</i>	15.25	
	<i>Problems</i>	15.25	
	<i>References and Suggested Readings</i>	15.26	
16.	Multiple Beam Interferometry		16.1
16.1	Introduction	16.1	
16.2	Multiple Reflections from a Plane Parallel Film	16.1	
16.3	The Fabry-perot Etalon	16.3	
16.4	The Fabry-perot Interferometer	16.5	
16.5	Resolving Power	16.6	
16.6	The Lummer-Gehrcke Plate	16.9	
16.7	Interference Filters	16.10	
	<i>Summary</i>	16.11	
	<i>Problems</i>	16.11	
	<i>References and Suggested Readings</i>	16.11	
17.	Coherence		17.1
17.1	Introduction	17.1	
17.2	The Linewidth	17.3	
17.3	The Spatial Coherence	17.4	
17.4	Michelson Stellar Interferometer	17.6	
17.5	Optical Beats	17.7	
17.6	Coherence Time and Linewidth via Fourier Analysis	17.9	
17.7	Complex Degree of Coherence and Fringe Visibility in Young's Double-hole Experiment	17.10	
17.8	Fourier Transform Spectroscopy	17.12	
	<i>Summary</i>	17.17	
	<i>Problems</i>	17.17	
	<i>References and Suggested Readings</i>	17.18	

Part 4 Diffraction

18.	Fraunhofer Diffraction: I		18.3
18.1	Introduction	18.3	
18.2	Single-slit Diffraction Pattern	18.4	
18.3	Diffraction by a Circular Aperture	18.8	
18.4	Directionality of Laser Beams	18.10	
18.5	Limit of Resolution	18.15	

- 18.6 Two-slit Fraunhofer Diffraction Pattern 18.17
- 18.7 N-slit Fraunhofer Diffraction Pattern 18.20
- 18.8 The Diffraction Grating 18.23
- 18.9 Oblique Incidence 18.26
- 18.10 X-ray Diffraction 18.27
- 18.11 The Self-focusing Phenomenon 18.31
- 18.12 Optical Media Technology-an Essay 18.33
 - Summary 18.36
 - Problems 18.36
 - References and Suggested Readings 18.38

19. Fraunhofer Diffraction: II and Fourier Optics

19.1

- 19.1 Introduction 19.1
- 19.2 The Fresnel Diffraction Integral 19.1
- 19.3 Uniform Amplitude and Phase Distribution 19.3
- 19.4 The Fraunhofer Approximation 19.3
- 19.5 Fraunhofer Diffraction by a Long Narrow Slit 19.3
- 19.6 Fraunhofer Diffraction by a Rectangular Aperture 19.4
- 19.7 Fraunhofer Diffraction by a Circular Aperture 19.5
- 19.8 Array of Identical Apertures 19.6
- 19.9 Spatial Frequency Filtering 19.7
- 19.10 The Fourier Transforming Property of a Thin Lens 19.10
 - Summary 19.12
 - Problems 19.12
 - References and Suggested Readings 19.12

20. Fresnel Diffraction

20.1

- 20.1 Introduction 20.1
- 20.2 Fresnel Half-period Zones 20.2
- 20.3 The Zone-plate 20.4
- 20.4 Fresnel Diffraction—A More Rigorous Approach 20.6
- 20.5 Gaussian Beam Propagation 20.8
- 20.6 Diffraction by a Straight Edge 20.10
- 20.7 Diffraction of a Plane Wave by a Long Narrow Slit and Transition to The Fraunhofer Region 20.15
 - Summary 20.18
 - Problems 20.19
 - References and Suggested Readings 20.20

21. Holography

21.1

- 21.1 Introduction 21.1
- 21.2 Theory 21.3
- 21.3 Requirements 21.6
- 21.4 Some Applications 21.6
 - Summary 21.8
 - Problems 21.9
 - References and Suggested Readings 21.9

Part 5 Electromagnetic Character of Light

22. Polarization and Double Refraction

22.1

- 22.1 Introduction 22.3
- 22.2 Production of Polarized Light 22.6
- 22.3 Malus' Law 22.9
- 22.4 Superposition of Two Disturbances 22.10
- 22.5 The Phenomenon of Double Refraction 22.13
- 22.6 Interference of Polarized Light: Quarter Wave Plates and Half Wave Plates 22.17

- 22.7 Analysis of Polarized Light 22.20
- 22.8 Optical Activity 22.21
- 22.9 Change in the SoP (State of Polarization) of a Light Beam
Propagating Through an Elliptic Core Single Mode Optical Fiber 22.22
- 22.10 Wollaston Prism 22.24
- 22.11 Rochon Prism 22.25
- 22.12 Plane Wave Propagation in Anisotropic Media 22.26
- 22.13 Ray Velocity and Ray Refractive Index 22.30
- 22.14 Jones Calculus 22.32
- 22.15 Faraday Rotation 22.33
- 22.16 Theory of Optical Activity 22.34
 - Summary* 22.36
 - Problems* 22.37
 - References and Suggested Readings* 22.39

23. Electromagnetic Waves

23.1

- 23.1 Maxwell's Equations 23.1
- 23.2 Plane Waves in a Dielectric 23.2
- 23.3 The Three-dimensional Wave Equation in a Dielectric 23.4
- 23.4 The Poynting Vector 23.5
- 23.5 Energy Density and Intensity of an Electromagnetic Wave 23.8
- 23.6 Radiation Pressure 23.9
- 23.7 The Wave Equation in a Conducting Medium 23.10
- 23.8 The Continuity Conditions 23.11
- 23.9 Physical Significance of Maxwell's Equations 23.12
 - Summary* 23.14
 - Problems* 23.14
 - References and Suggested Readings* 23.15

24. Reflection and Refraction of Electromagnetic Waves

24.1

- 24.1 Introduction 24.1
- 24.2 Reflection at an Interface of Two Dielectrics 24.1
- 24.3 Reflection by a Conducting Medium 24.14
- 24.4 Reflectivity of a Dielectric Film 24.15
 - Summary* 24.16
 - Problems* 24.17
 - References and Suggested Readings* 24.18

Part 6 Photons

25. The Particle Nature of Radiation

25.3

- 25.1 Introduction 25.4
- 25.2 The Photoelectric Effect 25.4
- 25.3 The Compton Effect 25.6
- 25.4 The Photon Mass 25.10
- 25.5 Angular Momentum of a Photon 25.10
 - Summary* 25.12
 - Problems* 25.13
 - References and Suggested Readings* 25.13

Part 7 Lasers & Fiber Optics

26. Lasers: An Introduction

26.3

- 26.1 Introduction 26.3
- 26.2 The Fiber Laser 26.9
- 26.3 The Ruby Laser 26.11

26.4	The He-Ne Laser	26.13	
26.5	Optical Resonators	26.14	
26.6	Einstein Coefficients and Optical Amplification	26.18	
26.7	The Line-shape Function	26.24	
26.8	Typical Parameters for a Ruby Laser	26.25	
26.9	Monochromaticity of the Laser Beam	26.26	
26.10	Raman Amplification and Raman Laser	26.27	
	<i>Summary</i>	26.30	
	<i>Problems</i>	26.31	
	<i>References and Suggested Readings</i>	26.32	
27.	Fiber Optics I: Basic Concepts and Ray Optics Considerations		27.3
27.1	Introduction	27.2	
27.2	Some Historical Remarks	27.2	
27.3	Total Internal Reflection	27.4	
27.4	The Optical Fiber	27.6	
27.5	Why Glass Fibers?	27.7	
27.6	The Coherent Bundle	27.7	
27.7	The Numerical Aperture	27.8	
27.8	Attenuation in Optical Fibers	27.9	
27.9	The Attenuation Limit	27.11	
27.10	Pulse Dispersion in Multimode Optical Fibers	27.11	
27.11	Dispersion and Maximum Bit Rates	27.14	
27.12	Fiber Optic Sensors	27.15	
	<i>Problems</i>	27.16	
	<i>References and Suggested Readings</i>	27.26	
28.	Fiber Optics II: Basic Waveguide Theory and Concept of Modes		28.1
28.1	Introduction	28.1	
28.2	Te Modes of a Symmetric Step Index Planar Waveguide	28.2	
28.3	Physical Understanding of Modes	28.5	
28.4	Te Modes of a Parabolic Index Planar Waveguide	28.7	
28.5	Tm Modes of a Symmetric Step Index Planar Waveguide	28.8	
28.6	Waveguide Theory and Quantum Mechanics	28.8	
	<i>Problems</i>	28.10	
	<i>References and Suggested Readings</i>	28.11	
29.	Fiber Optics III: Single Mode Fibers		29.1
29.1	Introduction	29.1	
29.2	Basic Equations	29.1	
29.3	Guided Modes of a Step Index Fiber	29.3	
29.4	Single Mode Fiber	29.6	
29.5	Pulse Dispersion in Single Mode Fibers	29.7	
29.6	Dispersion Compensating Fibers	29.9	
	<i>Problems</i>	29.12	
	<i>References and Suggested Readings</i>	29.12	
	Appendix A: Gamma Functions and Integrals Involving Gaussian Functions		A. 1
	Appendix B: Evaluation of the Integral		B. 1
	Appendix C: Diffraction of a Gaussian Beam		C. 1
	Appendix D: TE and TM Modes in Planar Waveguides		D. 1
	Name Index		I. 1
	Subject Index		I. 1