Contents

1 A Brief History 1

- **1.1** Prolegomenon 1
- **1.2** In the Beginning 1
- **1.3** From the Seventeenth Century 2
- **1.4** The Nineteenth Century 4
- **1.5** Twentieth-Century Optics 7

2 Wave Motion 10

- **2.1** One-Dimensional Waves 10
- **2.2** Harmonic Waves 14
- **2.3** Phase and Phase Velocity 18
- **2.4** The Superposition Principle 20
- **2.5** The Complex Representation 22
- **2.6** Phasors and the Addition of Waves 23
- **2.7** Plane Waves 24
- **2.8** The Three-Dimensional Differential Wave Equation 28
- **2.9** Spherical Waves 29
- **2.10** Cylindrical Waves 31
- **2.11** Twisted Light 31

  Problems 33

3 Electromagnetic Theory, Photons, and Light 37

- **3.1** Basic Laws of Electromagnetic Theory 38
- **3.2** Electromagnetic Waves 46
- **3.3** Energy and Momentum 49
- **3.4** Radiation 61
- **3.5** Light in Bulk Matter 68
- **3.6** The Electromagnetic-Photon Spectrum 75
- **3.7** Quantum Field Theory 82

  Problems 84

4 The Propagation of Light 88

- **4.1** Introduction 88
- **4.2** Rayleigh Scattering 88
- **4.3** Reflection 96
- **4.4** Refraction 100
- **4.5** Fermat's Principle 109
- **4.6** The Electromagnetic Approach 113
- **4.7** Total Internal Reflection 125
- **4.8** Optical Properties of Metals 131
- **4.9** Familiar Aspects of the Interaction of Light and Matter 134
- **4.10** The Stokes Treatment of Reflection and Refraction 139
- **4.11** Photons, Waves, and Probability 140

  Problems 143

5 Geometrical Optics 151

- **5.1** Introductory Remarks 151
- **5.2** Lenses 151
- **5.3** Stops 175
- **5.4** Mirrors 180
- **5.5** Prisms 191
- **5.6** Fiberoptics 196
- **5.7** Optical Systems 207
- **5.8** Wavefront Shaping 231
- **5.9** Gravitational Lensing 236

  Problems 238

6 More on Geometrical Optics 247

- **6.1** Thick Lenses and Lens Systems 247
- **6.2** Analytical Ray Tracing 251
- **6.3** Aberrations 258
- **6.4** GRIN Systems 276
- **6.5** Concluding Remarks 278

  Problems 278

7 The Superposition of Waves 282

- **7.1** The Addition of Waves of the Same Frequency 283
- **7.2** The Addition of Waves of Different Frequency 294
- **7.3** Anharmonic Periodic Waves 300
- **7.4** Nonperiodic Waves 310

  Problems 324

8 Polarization 330

8.1 The Nature of Polarized Light 330
8.2 Polarizers 338
8.3 Dichroism 339
8.4 Birefringence 343
8.5 Scattering and Polarization 353
8.6 Polarization by Reflection 355
8.7 Retarders 358
8.8 Circular Polarizers 365
8.9 Polarization of Polychromatic Light 366
8.10 Optical Activity 367
8.11 Induced Optical Effects—Optical Modulators 372
8.12 Liquid Crystals 376
8.13 A Mathematical Description of Polarization 379
Problems 384

9 Interference 390

9.1 General Considerations 390
9.2 Conditions for Interference 394
9.3 Wavefront-Splitting Interferometers 397
9.4 Amplitude-Splitting Interferometers 408
9.5 Types and Localization of Interference Fringes 424
9.6 Multiple-Beam Interference 425
9.7 Applications of Single and Multilayer Films 433
9.8 Applications of Interferometry 438
Problems 444

10 Diffraction 449

10.1 Preliminary Considerations 449
10.2 Fraunhofer Diffraction 457
10.3 Fresnel Diffraction 497
10.4 Kirchhoff's Scalar Diffraction Theory 524
10.5 Boundary Diffraction Waves 527
Problems 528

11 Fourier Optics 534

11.1 Introduction 534
11.2 Fourier Transforms 534
11.3 Optical Applications 544
Problems 575

12 Basics of Coherence Theory 580

12.1 Introduction 580
12.2 Fringes and Coherence 582
12.3 Visibility 586
12.4 The Mutual Coherence Function and the Degree of Coherence 589
12.5 Coherence and Stellar Interferometry 595
Problems 601

13 Modern Optics: Lasers and Other Topics 604

13.1 Lasers and Laserlight 604
13.2 Imagery—The Spatial Distribution of Optical Information 630
13.3 Holography 644
13.4 Nonlinear Optics 659
Problems 664

Appendix 1 669
Appendix 2 672
Table 1 673
Solutions to Selected Problems 677
Bibliography 700
Index 704
List of Tables 714