

Contents

Preface.	vii
Introduction.	1
chapter 1 Vector Analysis	8
1-1 Vector Algebra	8
1-2 Fields and Their Graphical Representations	11
1-3 Directional Derivatives and Gradient	12
1-4 Line Integrals	14
1-5 Divergence and Gauss' Theorem.	14
1-6 Curl and Stokes' Theorem	16
1-7 Time Derivatives	19
1-8 Introduction of Coordinate Systems and the Calculation of Derived Fields	19
1-9 A Few Identities	25
1-10 The Inverse Problem of Vector Analysis	25
1-11 Derived Fields of the Second Order	25
Problems	27
chapter 2 Sinusoidal Oscillations and Waves and Their Complex Representation.	30
2-1 Complex Numbers and Their Representations	30
2-2 Sinusoidal Oscillations in One Dimension	34
2-3 Oscillations in Three Dimensions. Complex Vectors	36
2-4 Sinusoidal Waves in Scalar Fields	40
2-5 Sinusoidal Waves in Vector Fields	42
2-6 Superposition and Decomposition of Oscillations and Waves.	44
2-7 Cases in Which the Complex Representation Cannot Be Used	46
Problems	47
chapter 3 The Microscopic Description of Matter and the Microscopic Maxwell Equations	51
3-1 Microscopic Description of Matter	51
3-2 Microscopic Maxwell Equations	57
3-3 Field about a Spherically Symmetric Static Charge	60
	xi

xii Contents

3-4	Principle of Superposition	61
3-5	Coulomb's Law and the Units of Charge and Current	61
3-6	Field around a Straight Wire Carrying a Steady Current	62
3-7	Force between Parallel Currents and the Value of c	64
3-8	Measurement of Electric and Magnetic Fields	65
3-9	Field of a Plane-parallel Condenser	67
3-10	Field of a Cylindrical Solenoid	68
3-11	Conservation of Charge	68
3-12	Faraday's Law of Induction	69
3-13	Nonexistence of Magnetic Charge	70
3-14	General Solution of the Maxwell Equations	71
3-15	Wave Equation	73
	Problems	74
chapter 4 Energy and Energy Flow in the Electromagnetic Field.		77
4-1	Work Done in Slowly Charging a Condenser	77
4-2	Work Done in Slowly Energizing a Solenoid	78
4-3	Effects When the Fields Are Built Up Rapidly	79
4-4	General Theorem on Energy	80
4-5	Discussion of the Energy Theorem	82
	Problems	84
chapter 5 Monochromatic Dipole Radiation		87
5-1	Formulas for the Fields of a General Monochromatic Dipole Oscillator	87
5-2	Field of a Linear Oscillator	90
5-3	Field for an Elliptical Motion	96
5-4	Wave Zone	96
5-5	Rate of Radiation by a Dipole Oscillator	98
5-6	Fields and Radiation in the Case of Several Oscillators	101
	Problems	105
chapter 6 Diffraction. A Preliminary Description		107
chapter 7 Fraunhofer Diffraction by N Identical Apertures.		115
7-1	Definition of Fraunhofer Diffraction	115
7-2	Coordinate System	117
7-3	General Principles for Identical Apertures	117
7-4	Calculation of the Geometric Difference of Path	119
7-5	General Formulas for the Diffraction Pattern	120
7-6	Abbreviated Notation. The Term Normal Irradiance	121
7-7	Case $N = 2$. Young's Experiment	121
7-8	Uniform Linear Array	124
7-9	Reciprocity Theorem and Sensitivity Pattern	128

7-10	Rectangular Array	128
7-11	Crossed Array	130
7-12	Applications of Regular Arrays	130
7-13	Michelson Stellar Interferometer.	133
7-14	Radio-frequency Telescopes	137
7-15	Grating Spectroscope	142
7-16	Random Array	146
	Problems	152

chapter 8 Treatment of Diffraction in the Scalar Approximation. The Kirchhoff Integral 156

8-1	Scalar Theory of Light	157
8-2	Kirchhoff Integral	159
8-3	Application to Diffraction.	163
8-4	Comments on the Kirchhoff Method	164
8-5	Reciprocity Theorem	166
8-6	Babinet's Principle.	166
8-7	Diffraction by Plane Mirrors	167

chapter 9 Application of the Kirchhoff Integral to Fraunhofer Diffraction 168

9-1	General Formulas	168
9-2	Special Form of Babinet's Principle	171
9-3	Rectangular Aperture	172
9-4	Circular Aperture	175
9-5	Diffraction Gratings with Rectangular Apertures	176
9-6	Resolving Power of Telescope and Microscope.	180
9-7	Sine Condition	183
	Problems	184

chapter 10 Application of the Kirchhoff Integral to Fresnel Diffraction 188

10-1	Rectangular Aperture	189
10-2	Limiting Case of a Large Aperture. Long Slit and Straight Edge	196
10-3	Transition to the Fraunhofer Case	199
10-4	Circular Aperture.	201
10-5	Limiting Case of a Large Aperture	204
10-6	Opaque Disk	205
10-7	Zone Plate.	206
10-8	Concluding Remarks on Fresnel Diffraction	207
	Problems	208

chapter 11 Fourier Analysis and Its Application to Optical Problems 210

11-1	Fourier Theorem	210
------	---------------------------	-----

xiv Contents

11-2	Examples of Fourier Transforms	213
11-3	Theorems on Fourier Integrals	216
11-4	Multiple Integrals	219
11-5	Vector Functions	220
11-6	Occurrence of Fourier Integrals in Fraunhofer Diffraction	220
11-7	Snell's Law. Resolving Power of a Prism.	221
11-8	Abbe's Theory of the Formation of Images in the Microscope	224
11-9	Phase-contrast Method	232
11-10	Rationale of the Fourier Analysis of Linear Systems.	236
11-11	Examples	238
	Problems	240
 chapter 12 Radiation from Lorentz Atoms		243
12-1	The Geissler Tube	243
12-2	Classical Model of the Gaseous Discharge.	245
12-3	Equation of Motion and Its Solution	247
12-4	Radiated Fields and Energy.	251
12-5	Spectrum of the Radiation	252
12-6	Spectrum in the Case of Many Emissions.	255
12-7	Thermal Broadening of Spectrum Lines	260
12-8	Pressure Broadening of Spectrum Lines	264
	Problems	268
 chapter 13 Polychromatic Waves		271
13-1	Polychromatic Waves and Their Sources	272
13-2	Integrating and Continuous Modes of Detection.	274
13-3	Propagation of a Wave from a Small Source through an Optical System	277
13-4	Examples of Transmission Functions and Calculation of Diffraction Patterns	281
13-5	Spectrographs and the Measurement of Energy Spectra and Power Spectra.	286
13-6	Incoherence of Independent Sources	291
13-7	Rule for Incoherent Sources.	293
13-8	Diffraction with Quasi-monochromatic Sources	294
13-9	Extended Sources.	296
13-10	Coherent and Partially Coherent Sources. Lateral Coherence in Wave Fields	299
13-11	Longitudinal Coherence in Wave Fields. Michelson Interferometer and Its Use as a Spectrograph	302
13-12	Polarization of Polychromatic Waves	309
13-13	Measurement of the Stokes Parameters	313
13-14	Properties and Interpretation of the Stokes Parameters.	317
13-15	Techniques for Problems Involving Polarization	320

13-16	Measurement of Spectrum and Coherence by Means of Beat Frequencies	323
	Problems	327
chapter 14 Scattering		334
14-1	Introductory Survey and Definitions	334
14-2	Rayleigh Scattering by a Single Particle	340
14-3	Definitions of Cross Sections	343
14-4	Scattering by a Lorentz Atom and by a Free Electron	344
14-5	Scattering by Gases	347
14-6	Diffraction by Crystals	351
14-7	Forward Scattering. Extinction	355
14-8	Force and Torque Exerted on a Body by Radiation. Radiation Pressure	357
	Problems	359
chapter 15 The Macroscopic Maxwell Theory		362
15-1	Derivation of the First Form of the Macroscopic Equations	363
15-2	Classification of Charges and Currents. Second Form of the Macroscopic Equations	365
15-3	Susceptibilities, Permeabilities, and Conductivity	369
15-4	Monochromatic Plane Waves in Homogeneous Media	371
15-5	Theory of the Complex Refractive Index	376
15-6	Energy Theorem	383
	Problems	385
chapter 16 Reflection and Transmission.		388
16-1	Collection of Formulas for a Single Medium	388
16-2	Boundary Conditions.	389
16-3	Reflection and Transmission at a Single Interface. General Formulas	390
16-4	Case of Two Transparent Media	397
16-5	Reflection from Metals	401
16-6	Layered Structures. Descriptive Survey	402
16-7	Airy Formula	403
16-8	Fabry-Perot Interferometer	405
16-9	Fabry-Perot Etalon as a Spectrometer.	408
16-10	Interference Filters	412
16-11	Single Dielectric Film	412
16-12	Multiple Dielectric Films	415
	Problems	417
chapter 17 Double Refraction		420
17-1	Introductory Survey	420
17-2	General Laws for Plane Waves	427
17-3	Nonactive Uniaxial Crystals.	428

xvi Contents

17-4	Nonactive Biaxial Crystals	430
17-5	Double Refraction at a Boundary	432
17-6	Applications of Double Refraction in Crystals	435
17-7	Optical Activity in Isotropic Media	438
17-8	Optically Active Anisotropic Crystals	441
	Problems	443
chapter 18 Magneto-optics and Electro-optics		445
18-1	Survey of Effects	445
18-2	Zeeman Effect	448
18-3	Faraday Effect	451
18-4	Cotton-Mouton Effect	453
18-5	Kerr Electro-optic Shutter	455
	Problems	457
chapter 19 Relation of Quantum to Classical Theory		460
19-1	Characterization of Radiation Fields	461
19-2	Radiation in Thermal Equilibrium. Cavity and Blackbody	462
19-3	Planck's Law and Its Forerunners	465
19-4	Old Quantum Theory of Atoms.	469
19-5	Einstein's Derivation of Planck's Law. Transition Probabilities	471
19-6	Lifetimes and Oscillator Strengths	473
19-7	Quantum Theory of Atoms and Radiation	477
19-8	Amplification by Stimulated Emission. Maser and Laser	486
19-9	Recoil. Doppler Shift. Mössbauer Effect	489
	Problems	491
Appendix A Electrical Units		493
Appendix B Radiation Field of a Dipole Oscillator.		508
Appendix C Table of Fresnel Integrals		522
Appendix D Calculation of the Spectral Profile of a Line Broadened by Thermal Motions and Collisions		524
Appendix E Mean Energy of an Oscillator in Cavity Radiation		527
Literature Cited.		530
Index		535