

CONTENTS

Preface xii

Guided Tour xvi

Chapter 1

Vector Analysis 1

- 1.1 Scalars and Vectors 1
- 1.2 Vector Algebra 2
- 1.3 The Rectangular Coordinate System 4
- 1.4 Vector Components and Unit Vectors 5
- 1.5 The Vector Field 8
- 1.6 The Dot Product 9
- 1.7 The Cross Product 12
- 1.8 Other Coordinate Systems: Circular
Cylindrical Coordinates 14
- 1.9 The Spherical Coordinate System 19
- References 22
- Chapter 1 Problems 23

Chapter 2

Coulomb's Law and Electric Field Intensity 26

- 2.1 The Experimental Law of Coulomb 27
- 2.2 Electric Field Intensity 30
- 2.3 Field Due to a Continuous Volume Charge
Distribution 34
- 2.4 Field of a Line Charge 37
- 2.5 Field of a Sheet of Charge 43
- 2.6 Streamlines and Sketches of Fields 45
- References 48
- Chapter 2 Problems 48

Chapter 3

Electric Flux Density, Gauss's Law, and Divergence 51

- 3.1 Electric Flux Density 51
- 3.2 Gauss's Law 55
- 3.3 Application of Gauss's Law: Some
Symmetrical Charge Distributions 59
- 3.4 Application of Gauss's Law: Differential
Volume Element 64
- 3.5 Divergence 67
- 3.6 Maxwell's First Equation (Electrostatics) 70
- 3.7 The Vector Operator ∇ and the Divergence
Theorem 72
- References 75
- Chapter 3 Problems 76

Chapter 4

Energy and Potential 80

- 4.1 Energy Expended in Moving a Point Charge in
an Electric Field 81
- 4.2 The Line Integral 82
- 4.3 Definition of Potential Difference and
Potential 87
- 4.4 The Potential Field of a Point Charge 89
- 4.5 The Potential Field of a System of Charges:
Conservative Property 91
- 4.6 Potential Gradient 95
- 4.7 The Dipole 101
- 4.8 Energy Density in the Electrostatic Field 106
- References 110
- Chapter 4 Problems 110

Chapter 5**Current and Conductors** 114

- 5.1 Current and Current Density 114
- 5.2 Continuity of Current 116
- 5.3 Metallic Conductors 118
- 5.4 Conductor Properties and Boundary Conditions 123
- 5.5 The Method of Images 128
- 5.6 Semiconductors 130
 - References 132
 - Chapter 5 Problems 132

Chapter 6**Dielectrics and Capacitance** 136

- 6.1 The Nature of Dielectric Materials 137
- 6.2 Boundary Conditions for Perfect Dielectric Materials 143
- 6.3 Capacitance 149
- 6.4 Several Capacitance Examples 152
- 6.5 Capacitance of a Two-Wire Line 155
- 6.6 Using Field Sketches to Estimate Capacitance in Two-Dimensional Problems 160
- 6.7 Current Analogies 165
 - References 167
 - Chapter 6 Problems 167

Chapter 7**Poisson's and Laplace's Equations** 172

- 7.1 Derivation of Poisson's and Laplace's Equations 173
- 7.2 Uniqueness Theorem 175
- 7.3 Examples of the Solution of Laplace's Equation 177
- 7.4 Example of the Solution of Poisson's Equation 184
- 7.5 Product Solution of Laplace's Equation 188

- 7.6 Solving Laplace's Equation Through Numerical Iteration 196
- References 202
- Chapter 7 Problems 203

Chapter 8**The Steady Magnetic Field** 210

- 8.1 Biot-Savart Law 210
- 8.2 Ampère's Circuital Law 218
- 8.3 Curl 225
- 8.4 Stokes' Theorem 232
- 8.5 Magnetic Flux and Magnetic Flux Density 237
- 8.6 The Scalar and Vector Magnetic Potentials 240
- 8.7 Derivation of the Steady-Magnetic-Field Laws 247
 - References 253
 - Chapter 8 Problems 253

Chapter 9**Magnetic Forces, Materials, and Inductance** 259

- 9.1 Force on a Moving Charge 260
- 9.2 Force on a Differential Current Element 261
- 9.3 Force Between Differential Current Elements 265
- 9.4 Force and Torque on a Closed Circuit 267
- 9.5 The Nature of Magnetic Materials 273
- 9.6 Magnetization and Permeability 276
- 9.7 Magnetic Boundary Conditions 281
- 9.8 The Magnetic Circuit 284
- 9.9 Potential Energy and Forces on Magnetic Materials 290
- 9.10 Inductance and Mutual Inductance 292
 - References 299
 - Chapter 9 Problems 299

Chapter 10**Time-Varying Fields and Maxwell's Equations** 306

- 10.1 Faraday's Law 306
- 10.2 Displacement Current 313
- 10.3 Maxwell's Equations in Point Form 317
- 10.4 Maxwell's Equations in Integral Form 319
- 10.5 The Retarded Potentials 321
 - References 325
 - Chapter 10 Problems 325

Chapter 11**Transmission Lines** 331

- 11.1 Physical Description of Transmission Line Propagation 332
- 11.2 The Transmission Line Equations 334
- 11.3 Lossless Propagation 336
- 11.4 Lossless Propagation of Sinusoidal Voltages 339
- 11.5 Complex Analysis of Sinusoidal Waves 341
- 11.6 Transmission Line Equations and Their Solutions in Phasor Form 343
- 11.7 Lossless and Low-Loss Propagation 345
- 11.8 Power Transmission and Loss Characterization 347
- 11.9 Wave Reflection at Discontinuities 350
- 11.10 Voltage Standing Wave Ratio 353
- 11.11 Transmission Lines of Finite Length 357
- 11.12 Some Transmission-Line Examples 360
- 11.13 Graphical Methods 364
- 11.14 Transient Analysis 375
 - References 388
 - Chapter 11 Problems 388

Chapter 12**The Uniform Plane Wave** 396

- 12.1 Wave Propagation in Free Space 396
- 12.2 Wave Propagation in Dielectrics 404
- 12.3 Poynting's Theorem and Wave Power 413

- 12.4 Propagation in Good Conductors: Skin Effect 416
- 12.5 Wave Polarization 423
 - References 430
 - Chapter 12 Problems 430

Chapter 13**Plane Wave Reflection and Dispersion** 434

- 13.1 Reflection of Uniform Plane Waves at Normal Incidence 434
- 13.2 Standing Wave Ratio 441
- 13.3 Wave Reflection from Multiple Interfaces 445
- 13.4 Plane Wave Propagation in General Directions 453
- 13.5 Plane Wave Reflection at Oblique Incidence Angles 456
- 13.6 Total Reflection and Total Transmission of Obliquely Incident Waves 462
- 13.7 Wave Propagation in Dispersive Media 465
- 13.8 Pulse Broadening in Dispersive Media 471
 - References 475
 - Chapter 13 Problems 476

Chapter 14**Guided Waves and Radiation** 480

- 14.1 Transmission Line Fields and Primary Constants 481
- 14.2 Basic Waveguide Operation 490
- 14.3 Plane Wave Analysis of the Parallel-Plate Waveguide 494
- 14.4 Parallel-Plate Guide Analysis Using the Wave Equation 503
- 14.5 Rectangular Waveguides 506
- 14.6 Planar Dielectric Waveguides 511
- 14.7 Optical Fiber 517
- 14.8 Basic Antenna Principles 527
 - References 537
 - Chapter 14 Problems 537

Appendix A**Vector Analysis** 542

- A.1 General Curvilinear Coordinates 542
- A.2 Divergence, Gradient, and Curl in General Curvilinear Coordinates 543
- A.3 Vector Identities 545

Appendix B**Units** 546Appendix C**Material Constants** 551Appendix D**Origins of the Complex Permittivity** 554Appendix E**Answers to Odd-Numbered Problems** 561**Index** 567