CONTENTS

Preface xii

Chapter 1
Vector Analysis 1

1.1 Scalars and Vectors 1
1.2 Vector Algebra 2
1.3 The Rectangular Coordinate System 3
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 11
1.8 Other Coordinate Systems: Circular Cylindrical Coordinates 13
1.9 The Spherical Coordinate System 18
References 22
Chapter 1 Problems 22

Chapter 2
Coulomb's Law and Electric Field Intensity 26

2.1 The Experimental Law of Coulomb 26
2.2 Electric Field Intensity 29
2.3 Field Arising from a Continuous Volume Charge Distribution 33
2.4 Field of a Line Charge 35
2.5 Field of a Sheet of Charge 39
2.6 Streamlines and Sketches of Fields 41
References 44
Chapter 2 Problems 44

Chapter 3
Electric Flux Density, Gauss's Law, and Divergence 48

3.1 Electric Flux Density 48
3.2 Gauss's Law 52
3.3 Application of Gauss's Law: Some Symmetrical Charge Distributions 56
3.4 Application of Gauss's Law: Differential Volume Element 61
3.5 Divergence and Maxwell's First Equation 64
3.6 The Vector Operator ∇ and the Divergence Theorem 67
References 70
Chapter 3 Problems 71

Chapter 4
Energy and Potential 75

4.1 Energy Expended in Moving a Point Charge in an Electric Field 76
4.2 The Line Integral 77
4.3 Definition of Potential Difference and Potential 82
4.4 The Potential Field of a Point Charge 84
4.5 The Potential Field of a System of Charges: Conservative Property 86
4.6 Potential Gradient 90
4.7 The Electric Dipole 95
4.8 Energy Density in the Electrostatic Field 100
References 104
Chapter 4 Problems 105

Chapter 5
Conductors and Dielectrics 109

5.1 Current and Current Density 110
5.2 Continuity of Current 111
5.3 Metallic Conductors 114
5.4 Conductor Properties and Boundary Conditions 119
5.5 The Method of Images 124
5.6 Semiconductors 126
5.7 The Nature of Dielectric Materials 127
5.8 Boundary Conditions for Perfect Dielectric Materials 133
References 137
Chapter 5 Problems 138

Chapter 6
Capacitance 143

6.1 Capacitance Defined 143
6.2 Parallel-Plate Capacitor 145
6.3 Several Capacitance Examples 147
6.4 Capacitance of a Two-Wire Line 150
6.5 Using Field Sketches to Estimate Capacitance in Two-Dimensional Problems 154
6.6 Poisson's and Laplace's Equations 160
6.7 Examples of the Solution of Laplace's Equation 162
6.8 Example of the Solution of Poisson's Equation: the *p-n* Junction Capacitance 169
References 172
Chapter 6 Problems 173

Chapter 7
The Steady Magnetic Field 180

7.1 Biot-Savart Law 180
7.2 Ampère's Circuital Law 188
7.3 Curl 195
7.4 Stokes' Theorem 202
7.5 Magnetic Flux and Magnetic Flux Density 207
7.6 The Scalar and Vector Magnetic Potentials 210
7.7 Derivation of the Steady-Magnetic-Field Laws 217
References 223
Chapter 7 Problems 223

Chapter 8
Magnetic Forces, Materials, and Inductance 230

8.1 Force on a Moving Charge 230
8.2 Force on a Differential Current Element 232
8.3 Force between Differential Current Elements 236
8.4 Force and Torque on a Closed Circuit 238
8.5 The Nature of Magnetic Materials 244
8.6 Magnetization and Permeability 247
8.7 Magnetic Boundary Conditions 252
8.8 The Magnetic Circuit 255
8.9 Potential Energy and Forces on Magnetic Materials 261
8.10 Inductance and Mutual Inductance 263
References 270
Chapter 8 Problems 270

Chapter 9
Time-Varying Fields and Maxwell's Equations 277

9.1 Faraday's Law 277
9.2 Displacement Current 284
9.3 Maxwell's Equations in Point Form 288
9.4 Maxwell's Equations in Integral Form 290
9.5 The Retarded Potentials 292
References 296
Chapter 9 Problems 296

Chapter 10
Transmission Lines 301

10.1 Physical Description of Transmission Line Propagation 302
10.2 The Transmission Line Equations 304
10.3 Lossless Propagation 306
10.4 Lossless Propagation of Sinusoidal Voltages 309
10.5 Complex Analysis of Sinusoidal Waves 311
10.6 Transmission Line Equations and Their Solutions in Phasor Form 313
10.7 Low-Loss Propagation 315
10.8 Power Transmission and The Use of Decibels in Loss Characterization 317
10.9 Wave Reflection at Discontinuities 320
10.10 Voltage Standing Wave Ratio 323
10.11 Transmission Lines of Finite Length 327
10.12 Some Transmission Line Examples 330
10.13 Graphical Methods: The Smith Chart 334
10.14 Transient Analysis 345
References 358
Chapter 10 Problems 358

Chapter 11
The Uniform Plane Wave 367

11.1 Wave Propagation in Free Space 367
11.2 Wave Propagation in Dielectrics 375
11.3 Poynting's Theorem and Wave Power 384
11.4 Propagation in Good Conductors: Skin Effect 387
11.5 Wave Polarization 394
References 401
Chapter 11 Problems 401

Chapter 12
Plane Wave Reflection and Dispersion 406

12.1 Reflection of Uniform Plane Waves at Normal Incidence 406
12.2 Standing Wave Ratio 413
12.3 Wave Reflection from Multiple Interfaces 417
12.4 Plane Wave Propagation in General Directions 425
12.5 Plane Wave Reflection at Oblique Incidence Angles 428
12.6 Total Reflection and Total Transmission of Obliquely Incident Waves 434
12.7 Wave Propagation in Dispersive Media 437
12.8 Pulse Broadening in Dispersive Media 443
References 447
Chapter 12 Problems 448

Chapter 13
Guided Waves 453

13.1 Transmission Line Fields and Primary Constants 453
13.2 Basic Waveguide Operation 463
13.3 Plane Wave Analysis of the Parallel-Plate Waveguide 467
13.4 Parallel-Plate Guide Analysis Using the Wave Equation 476
13.5 Rectangular Waveguides 479
13.6 Planar Dielectric Waveguides 490
13.7 Optical Fiber 496
References 506
Chapter 13 Problems 506

Chapter 14
Electromagnetic Radiation and Antennas 511

14.1 Basic Radiation Principles: The Hertzian Dipole 511
14.2 Antenna Specifications 518
14.3 Magnetic Dipole 523
14.4 Thin Wire Antennas 525
14.5 Arrays of Two Elements 533
14.6 Uniform Linear Arrays 537
14.7 Antennas as Receivers 541
References 548
Chapter 14 Problems 548

Appendix A
Vector Analysis 553

A.1 General Curvilinear Coordinates 553
A.2 Divergence, Gradient, and Curl in General Curvilinear Coordinates 554
A.3 Vector Identities 556

Appendix B
Units 557

Appendix C
Material Constants 562

Appendix D
The Uniqueness Theorem 565

Appendix E
Origins of the Complex Permittivity 567

Appendix F
Answers to Odd-Numbered Problems 574

Index 580