Seventh Edition

ENGINEERING ELECTROMAGNETICS

WILLIAM H. HAYT, JR. John A. Buck

McGRAW-HILL INTERNATIONAL EDITION

CONTENTS

	Preface xii Guided Tour xvi	Ele	apter 3 ectric Flux Density, Gauss's Law, d Divergence 51
Ve (.1	Vector Components and Unit Vectors 5 The Vector Field 8 The Dot Product 9 The Cross Product 12 Other Coordinate Systems: Circular	3.2 3.3 3.4 3.5	Symmetrical Charge Distributions 59 Application of Gauss's Law: Differential Volume Element 64 Divergence 67 Maxwell's First Equation (Electrostatics) 70 The Vector Operator ∇ and the Divergence Theorem 72 References 75
1.9	Cylindrical Coordinates 14 The Spherical Coordinate System 19 References 22 Chapter 1 Problems 23	En	Chapter 3 Problems 76 Apter 4 ergy and Potential 80
Chapter 2 Coulomb's Law and Electric Field Intensity 26			Energy Expended in Moving a Point Charge in an Electric Field 81 The Line Integral 82 Definition of Potential Difference and
2.2	The Experimental Law of Coulomb 27 Electric Field Intensity 30 Field Due to a Continuous Volume Charge Distribution 34 Field of a Line Charge 37 Field of a Sheet of Charge 43 Streamlines and Sketches of Fields 45 References 48 Chapter 2 Problems 48	4.4 4.5 4.6 4.7 4.8	Potential 87 The Potential Field of a Point Charge 89 The Potential Field of a System of Charges: Conservative Property 91 Potential Gradient 95 The Dipole 101 Energy Density in the Electrostatic Field 106 References 110 Chapter 4 Problems 110

Contents ix

Chapter 5		7.6	Solving Laplace's Equation Through
Current and Conductors 114			Numerical Iteration 196
5.1	Current and Current Density 114		References 202
5.2	Continuity of Current 116		Chapter 7 Problems 203
5.3	Metallic Conductors 118		
5.4	Conductor Properties and Boundary Conditions 123		apter 8 e Steady Magnetic Field 210
5.5	The Method of Images 128	8.1	Biot-Savart Law 210
5.6	Semiconductors 130	8.2	Ampère's Circuital Law 218
	References 132	8.3	Curl 225
	Chapter 5 Problems 132	8.4	Stokes' Theorem 232
Cha	apter 6	8.5	Magnetic Flux and Magnetic Flux Density 237
	lectrics and Capacitance 136	8,6	The Scalar and Vector Magnetic
6.1	The Nature of Dielectric Materials 137		Potentials 240
. –	Boundary Conditions for Perfect	8,7	Derivation of the Steady-Magnetic-Field
0.2	Dielectric Materials 143		Laws 247
6.3	Capacitance 149		References 253
6.4	Several Capacitance Examples 152		Chapter 8 Problems 253
6.5	Capacitance of a Two-Wire Line 155		
6.6	Using Field Sketches to Estimate Capacitance	Cha	apter 9
	in Two-Dimensional Problems 160		gnetic Forces, Materials,
6.7	Current Analogies 165	and	I Inductance 259
	References 167	9.1	Force on a Moving Charge 260
	Chapter 6 Problems 167	9.2	Force on a Differential Current Element 261
<u>Cha</u>	pter_ 7 _	9,3	Force Between Differential Current Elements 265
Poi	sson's and Laplace's	9.4	Force and Torque on a Closed Circuit 267
Equations 172		9.5	The Nature of Magnetic Materials 273
7.1	Derivation of Poisson's and Laplace's	9.6	Magnetization and Permeability 276
	Equations 173	9.7	Magnetic Boundary Conditions 281
7.2	Uniqueness Theorem 175	9.8	The Magnetic Circuit 284
7.3	Examples of the Solution of Laplace's Equation 177		Potential Energy and Forces on Magnetic Materials 290
7.4	Example of the Solution of Poisson's Equation 184	9.10	Inductance and Mutual Inductance 292 References 299
7.5	Product Solution of Laplace's Equation 188		Chapter 9 Problems 299

Chapter 10 Time-Varying Fields and Maxwell's		12.4	Propagation in Good Conductors: Skin Effect 416
Equations 306		12.5	Wave Polarization 423
-			References 430
10.1	Faraday's Law 306		Chapter 12 Problems 430
10.2	Displacement Current 313		1.0
10.3	Maxwell's Equations in Point Form 317	•	oter 13
10.4	Maxwell's Equations in Integral Form 319		ne Wave Reflection
10.5	The Retarded Potentials 321	and Dispersion 434	Dispersion 434
	References 325 Chapter 10 Problems 325	13.1	Reflection of Uniform Plane Waves at Normal Incidence 434
Char	nter ¶¶	13.2	Standing Wave Ratio 441
<u>Chapter 11</u> Transmission Lines 331		13.3	Wave Reflection from Multiple Interfaces 445
11.1	Physical Description of Transmission Line Propagation 332	13.4	Plane Wave Propagation in General Directions 453
11.2	The Transmission Line Equations 334	13.5	Plane Wave Reflection at Oblique
11.3	Lossless Propagation 336		Incidence Angles 456
11.4	Lossless Propagation of Sinusoidal Voltages 339	13.6	Total Reflection and Total Transmission of Obliquely Incident Waves 462
11.5	Complex Analysis of Sinusoidal Waves 341	13.7	Wave Propagation in Dispersive Media 465
11.6	Transmission Line Equations and Their	13.8	Pulse Broadening in Dispersive Media 471
	Solutions in Phasor Form 343		References 475
11.7	Lossless and Low-Loss Propagation 345		Chapter 13 Problems 476
11.8	Power Transmission and Loss	٥,	
	Characterization 347		pter 14
	Wave Reflection at Discontinuities 350	Gui	ded Waves and Radiation 480
	Voltage Standing Wave Ratio 353 Transmission Lines of Finite Length 357	14.1	Transmission Line Fields and Primary Constants 481
11.12	Some Transmission-Line Examples 360	14.2	Basic Waveguide Operation 490
	Graphical Methods 364	14.3	Plane Wave Analysis of the Parallel-Plate
11.14	Transient Analysis 375		Waveguide 494
	References 388 Chapter 11 Problems 388	14.4	Parallel-Plate Guide Analysis Using the Wave Equation 503
~ !	4.40	14.5	Rectangular Waveguides 506
Chapter 12		14.6	Planar Dielectric Waveguides 511
The	Uniform Plane Wave 396	14.7	Optical Fiber 517
12.1	Wave Propagation in Free Space 396	14.8	Basic Antenna Principles 527
12.2	Wave Propagation in Dielectrics 404		References 537
12,3	Poynting's Theorem and Wave Power 413		Chapter 14 Problems 537

Appendix A	Appendix D	
Vector Analysis 542	Origins of the Complex	
A.1 General Curvilinear Coordinates 542	Permittivity 554	
A.2 Divergence, Gradient, and Curl in General Curvilinear Coordinates 543		
A.3 Vector Identities 545	Appendix E	
Appendix B	Answers to Odd-Numbered	
Units 546	Problems 561	
Appendix C		
Material Constants 551	Index 567	