## Contents

Pre	face		Xi
1	Elec	otroma anotic yyayas	1
1		tromagnetic waves	
	1.1	Introduction	1
	1.2	Maxwell's equations	2 5
	1.3	Electromagnetic waves in non-conducting media	
	1.4	Energy flow in an electromagnetic wave	8
	1.5	Electromagnetic waves in conducting materials	9
	1.6	Propagation of waves in plasmas	12
	1.7	Polarization of waves	14
	1.8	Propagation in gyromagnetic media	15
	1.9	Boundary conditions	18
	1.10	Conclusion	23
		Exercises	23
		a contract the second contract the	
2	Way	ves guided by perfectly conducting boundaries	25
	2.1	TEM transmission lines	25
	2.2	Reflection of waves by a conducting plane	27
	2.3	Transverse electric waves	29
	2.4	Transverse magnetic waves	34
	2.5	Propagation in a rectangular waveguide	36
	2.6	Power flow in a rectangular waveguide	40
	2.7	Higher-order modes in a rectangular waveguide	43
	2.8	Other waveguides	48
	2.9	Conclusion	49
		Exercises	50
101	177		<b>51</b>
3		ves with dielectric boundaries	51
	3.1		51
	3.2	Total internal reflection	52
	3.3	The Brewster angle	53
	3.4	Dielectric waveguides	54

CC	INI	FN	TC

ix

	3.5 Mono-mode and multi-mode optical fibres	58	7 Flagtromagnetic reconstruction and Clause	1.5
	3.6 Radomes, windows and optical blooming	60	7 Electromagnetic resonators and filters	15
	3.7 Quasi TEM waveguides	63	7.1 Introduction 7.2 Transmission-line resonators	15
	3.8 Non-TEM waveguides	67		16
	3.9 Conclusion	69	7.3 Cavity resonators	16
	Exercises	69	7.4 Effect of resonance on screened enclosures	17
		0,	7.5 Dielectric resonators	17
4	Waves with imperfectly conducting boundaries	71	7.6 Fabry–Pérot resonators	17
	4.1 Waves incident normally on a conducting surface	71	7.7 Filter theory	17
	4.2 Transmission through a thin conducting sheet	75	7.8 Transmission-line filters	18
	4.3 Electromagnetic screening	77	7.9 Waveguide filters	18:
	4.4 Waves incident obliquely on a conducting surface	82	7.10 Optical filters	18
	4.5 Losses in transmission lines and waveguides	84	7.11 Conclusion	183
	4.6 Microwave attenuators		Exercises	183
	4.7 Microwave loads	86		
	4.8 Conclusion	89	8 Ferrite devices	190
	Exercises	91	8.1 Introduction	190
	LACICISCS	92	8.2 Microwave properties of ferrites	190
5	Antennas	0.3	8.3 Resonance isolators	194
J	5.1 Introduction	93	8.4 Phase shifters and circulators	190
		93	8.5 Junction circulators	198
	S	93	8.6 Faraday rotation devices	200
	1	95	8.7 Edge mode devices	202
		95	8.8 YIG filters	204
	5.5 The reciprocity theorem	103	8.9 Conclusion	205
	5.6 Small magnetic dipole	106	Exercises	205
	5.7 Half-wave dipole	108	Excitises	203
	5.8 Dipole arrays	110	9 Solid state microwave devices	200
	5.9 Radiation from apertures	114	9.1 Introduction	206
	5.10 Slot antennas	118	9.2 Semiconductor materials	206
	5.11 Phased array antennas	121	9.3 Diodes	206
	5.12 Conclusion	123	9.4 Transistors	209
	Exercises	123		215
			The state of the s	218
6	Coupling between wave-guiding systems	125		221
	6.1 Introduction	125		223
	6.2 Discontinuities	125	9.8 Amplifiers	225
	6.3 Broadband matching techniques	130	9.9 Monolithic microwave integrated circuits	227
	6.4 Coupling without change of mode	133	9.10 LEDs and laser diodes	227
	6.5 Coupling with change of mode	137	9.11 Conclusion	229
	6.6 Coupling by apertures	142	10 V	
	6.7 Effect of holes in screens on screening effectiveness	144	10 Vacuum devices	230
	6.8 Waveguide directional couplers	147	10.1 Introduction	230
	6.9 Distributed coupling	151	10.2 Space-charge waves	230
	6.10 Conclusion	156	10.3 Klystron amplifiers	234
	Exercises		10.4 Slow-wave structures	242
		156	10.5 Travelling wave tubes	248

x

## CONTENTS

	rossed-field tubes	254		
	ast-wave devices	257		
	lectron accelerators	260		
	onclusion	262		
E	xercises	262		
11 Micros	enical control of calindy			
	wave measurements	264		
	ntroduction	264		
	leasurement of frequency	264		
	leasurement of power	266		
	leasurement of gain and loss	267		
	leasurement of return loss	271		
	leasurement of impedance	272		
	ime-domain reflectometry	275		
	pectrum analyser measurements	277		
11.9 E	lectromagnetic compatibility measurements	278		
	easurement of resonators	280		
	easurement of dielectric properties	282		
	onclusion	284		
E	xercises	284		
12 System	susing alastromagnatic visus	204		
	s using electromagnetic waves	286		
	troduction earlier of the	286		
	adio wave propagation	286		
	adio communications	291		
	elevision broadcasting	293		
	icrowave communications	294		
	adar	-297		
	ectronic countermeasures	301		
	dustrial and domestic applications	302		
12.9 M	edical applications	305		
12.10 Co	omputer-aided design of microwave systems	305		
	onclusion	306		
Ex	recises =	306		
References		307		
references		307		
Appendix A	A Transmission lines	310		
Appendix B Vector formulae				
Appendix C Constants and properties of materials				
Appendix D Answers to selected problems				
Index				