

Contents

<i>Preface</i>	<i>page</i> xiii
1 Introduction	1
2 Interactions, Units, and Magnitudes	3
2.1 Units	3
2.2 Particles and Forces	7
2.3 Orders of Magnitude	10
2.4 Selected References	12
2.5 Problems	13
3 Noise in Physical Systems	14
3.1 Random Variables	14
3.1.1 Expectation Values	14
3.1.2 Spectral Theorems	15
3.2 Probability Distributions	18
3.2.1 Binomial	18
3.2.2 Poisson	18
3.2.3 Gaussian	19
3.2.4 Central Limit Theorem	21
3.3 Noise Mechanisms	22
3.3.1 Shot Noise	22
3.3.2 Johnson Noise	23
3.3.3 $1/f$ Noise and Switching Noise	24
3.3.4 Amplifier Noise	25
3.4 Thermodynamics and Noise	27
3.4.1 Thermodynamics and Statistical Mechanics	27
3.4.2 Equipartition Theorem	30
3.4.3 Fluctuation–Dissipation Theorem	31
3.5 Selected References	34
3.6 Problems	35
4 Information in Physical Systems	36
4.1 Information	36
4.2 Channel Capacity	40

4.3	The Gaussian Channel	42
4.4	Fisher Information	45
4.5	Information and Thermodynamics	48
4.6	Selected References	49
4.7	Problems	49
5	Electromagnetic Fields and Waves	51
5.1	Vector Calculus	51
5.1.1	Vectors	51
5.1.2	Differential Operators	53
5.1.3	Integral Relationships	55
5.2	Statics	56
5.2.1	Electrostatics	56
5.2.2	Magnetostatics	60
5.2.3	Multipoles	63
5.3	Dynamics	66
5.3.1	Maxwell's Equations	66
5.3.2	Boundary Conditions	68
5.3.3	Electromagnetic Units	70
5.4	Radiation and Energy	71
5.4.1	Waves	71
5.4.2	Electromagnetic Energy	72
5.5	Selected References	74
5.6	Problems	74
6	Circuits, Transmission Lines, and Waveguides	76
6.1	Circuits	76
6.1.1	Current and Voltage	76
6.1.2	Kirchhoff's Laws	77
6.1.3	Resistance	77
6.1.4	Power	79
6.1.5	Capacitance	79
6.1.6	Inductance	80
6.2	Wires and Transmission Lines	81
6.2.1	Skin Depth	81
6.2.2	Transmission Lines	83
6.2.3	Wave Solutions	85
6.2.4	Reflections and Terminations	87
6.3	Waveguides	90
6.3.1	Governing Equations	90
6.3.2	Rectangular Waveguides	92
6.3.3	Circular Waveguides	93
6.3.4	Dielectric Waveguides and Fiber Optics	93
6.4	Selected References	95
6.5	Problems	96

	<i>Contents</i>	ix
7 Antennas		98
7.1 Time-Dependent Potentials		98
7.2 Dipole Radiation		102
7.2.1 Infinitesimal Length		102
7.2.2 Finite Length		104
7.3 Duality and Reciprocity		106
7.4 Antenna Types		109
7.5 Selected References		111
7.6 Problems		111
8 Optics		112
8.1 Reflection and Refraction		112
8.2 Geometrical Optics		117
8.2.1 Ray Matrices		119
8.2.2 Optical Transforms		120
8.3 Beyond Geometrical Optics		122
8.4 Selected References		126
8.5 Problems		126
9 Lensless Imaging and Inverse Problems		128
9.1 Matched Filters and Synthetic Lenses		128
9.2 Coherent Imaging		131
9.3 Computed Tomography		134
9.4 Magnetic Resonance Imaging		135
9.5 Inverse Problems		138
9.6 Selected References		139
9.7 Problems		139
10 Semiconductor Materials and Devices		141
10.1 Quantum Statistical Mechanics		141
10.2 Electronic Structure		143
10.3 Junctions, Diodes, and Transistors		151
10.4 Logic		156
10.5 Limits		161
10.6 Selected References		163
10.7 Problems		163
11 Generating, Detecting, and Modulating Light		165
11.1 Generation		165
11.1.1 Incandescence		165
11.1.2 Luminescence: LEDs, Lasers, and Flat Panels		167
11.2 Detection		172
11.3 Modulation		177
11.3.1 Polarization		177
11.3.2 Liquid Crystals		179
11.3.3 Smoke and Mirrors		183

x	<i>Contents</i>	
	11.4 Selected References	186
	11.5 Problems	186
12	Magnetic Storage	187
12.1	Magnetism	187
12.1.1	Diamagnetism	189
12.1.2	Paramagnetism	190
12.1.3	Ferro-, Antiferro-, and Ferri-magnetism	192
12.2	Magnetic Recording	197
12.2.1	Magnetic Media	197
12.2.2	Magnetic Recording	198
12.2.3	Recording Systems	200
12.3	Selected References	201
12.4	Problems	201
13	Measurement and Coding	203
13.1	Instrumentation	203
13.1.1	Amplifiers	203
13.1.2	Grounding, Shielding, and Leads	207
13.1.3	Bridges	209
13.2	Modulation and Detection	211
13.2.1	Synchronous Detection	211
13.2.2	Phase Detection and Encoding	213
13.2.3	Spread Spectrum	216
13.2.4	Digitization	220
13.3	Coding	222
13.3.1	Compression	222
13.3.2	Error Correction	225
13.3.3	Channel Coding	227
13.3.4	Cryptography	228
13.4	Selected References	229
13.5	Problems	229
14	Transducers	231
14.1	Many-Body Effects	231
14.1.1	Superconductivity	232
14.1.2	SQUIDS	235
14.2	Non-Equilibrium Thermodynamics	236
14.2.1	Thermoelectricity	239
14.2.2	Piezoelectricity	242
14.3	Relativity	243
14.3.1	Clocks	243
14.3.2	Time	246
14.3.3	Position	249
14.4	Selected References	251
14.5	Problems	251

15	Quantum Computing and Communications	252
15.1	Quantum Mechanics	253
15.1.1	States and Operators	253
15.1.2	Angular Momentum	259
15.1.3	Density Matrices	263
15.2	Information	266
15.3	Communications	269
15.3.1	Cryptography	269
15.3.2	Circuits	270
15.3.3	Teleportation	271
15.3.4	Error Correction	273
15.4	Computation	275
15.4.1	Searching	276
15.4.2	Transforms and Factoring	278
15.4.3	Simulation	281
15.4.4	Experimental Implementation	282
15.5	Selected References	284
15.6	Problems	285
 <i>Appendix 1</i> Problem Solutions		 286
A1.1	Introduction	286
A1.2	Interactions, Units, and Magnitudes	286
A1.3	Noise in Physical Systems	291
A1.4	Information in Physical Systems	296
A1.5	Electromagnetic Fields and Waves	300
A1.6	Circuits, Transmission Lines, and Wave Guides	305
A1.7	Antennas	309
A1.8	Optics	311
A1.9	Lensless Imaging and Inverse Problems	317
A1.10	Semiconductor Materials and Devices	322
A1.11	Generating, Modulating, and Detecting Light	327
A1.12	Magnetic Storage	330
A1.13	Measurement and Coding	334
A1.14	Transducers	338
A1.15	Quantum Computing and Communication	342
 <i>Bibliography</i>		 347
<i>Index</i>		362