

## Contents

<b>Preface</b>	<i>XIII</i>	
<b>1</b>	<b>Nonstationary Perturbations</b>	1
1.1	Transition Probability	1
1.2	Perturbative Solution	2
1.3	Formal Series	5
1.4	Adiabatic Perturbations	7
1.5	Adiabatic Perturbation Theory	8
1.6	Nonadiabatic Transitions	10
1.7	Geometric Phase	13
1.8	Sudden Perturbations	16
1.9	Shake-Off Processes	19
<b>2</b>	<b>Periodic Perturbations</b>	23
2.1	Golden Rule	23
2.2	Beyond the First Order	26
2.3	Degenerate States	26
2.4	Quasienergy	28
2.5	Final States in the Continuum	29
2.6	Rotating Wave Approximation	35
2.7	Interaction with the Quantized Field	38
2.8	Dressed States	41
2.9	Super-Radiance	42
<b>3</b>	<b>Scattering of Fast Charged Particles</b>	47
3.1	Scattering and Cross Section	47
3.2	Rutherford Scattering	49
3.3	Static Form-Factor	51
3.4	Screening	54
3.5	Atomic Excitation and Ionization	56
3.6	Energy Losses	58
3.7	Coulomb Excitation	60
<b>4</b>	<b>Photons</b>	63
4.1	Introduction: Classical and Quantum Field	63

4.2	Hamiltonian Description of the Radiation Field	64
4.3	Quantization of the Radiation Field	67
4.4	Photon Wave Function	71
4.5	Vector Spherical Harmonics	73
4.6	Casimir Effect	75
4.7	Euler–Maclaurin Summation Formula	77
4.8	Lamb Shift	79
4.9	Interaction of Radiation with Matter	82
<b>5</b>	<b>Photoabsorption and Photoemission</b>	87
5.1	Einstein Coefficients; Masers and Lasers	87
5.2	Photoabsorption	91
5.3	Long Wavelength Limit	92
5.4	Higher Multipole Transitions	95
5.5	Stimulated and Spontaneous Radiation	97
5.6	Dipole Radiation	98
5.7	Selection Rules and Examples	100
5.8	Photoelectric Effect	103
<b>6</b>	<b>Dispersion and the Scattering of Light</b>	107
6.1	Macroscopic Description	107
6.2	Linear Response	108
6.3	Causality	110
6.4	Dielectric Function	112
6.5	Dispersion Properties	114
6.6	Quantum Damping	116
6.7	Dispersion Relations	118
6.8	Description of Scattering	119
6.9	Scattering Cross Section	121
6.10	Coherent Scattering	123
6.11	Resonance Fluorescence	124
6.12	Scattering off Many Centers	125
<b>7</b>	<b>Basics of Quantum Scattering</b>	129
7.1	Scattering and Observables	129
7.2	Classical Scattering and Cross Section	130
7.3	Scattering Matrix	133
7.4	Transition Rate	134
7.5	Born Approximation	136
7.6	Continuity Equation	138
7.7	Elastic Scattering	139
7.8	Unitarity and Optical Theorem	140
7.9	Green Function	142
7.10	Born Series	145
7.11	Validity of the Born Approximation	148
7.12	Scattering at High Energies	150

<b>8</b>	<b>Method of Partial Waves</b>	153
8.1	Partial Wave Analysis	153
8.2	Elastic and Inelastic Cross Sections	155
8.3	Elastic Phase Shifts	156
8.4	Analyticity	157
8.5	Scattering at Low Energies: Examples	158
8.6	Phases and Their Energy Behavior	162
8.7	Scattering Length	165
8.8	Resonance Scattering at Low Energies	168
8.9	Effective Radius	171
8.10	Scattering with Spin–Orbit Interaction	172
8.11	Polarization and Azimuthal Asymmetry	175
<b>9</b>	<b>More on Scattering</b>	179
9.1	Classical and Non-classical Scattering	179
9.2	Semiclassical Amplitude	180
9.3	Semiclassical Phases	181
9.4	Relation to the Eikonal Approximation	185
9.5	Diffraction Scattering	186
9.6	Diffraction from a Black Sphere	188
9.7	Optical Model	190
9.8	Multiple Scattering in the Medium	192
9.9	Coherent Scattering in Crystals	196
<b>10</b>	<b>Reactions, Decays and Resonances</b>	199
10.1	Reaction Channels	199
10.2	Scattering Matrix for Many-Channel Reactions	200
10.3	Detailed Balance	202
10.4	Cross Sections for Slow Particles	204
10.5	Thresholds and Unitarity	206
10.6	Isolated Resonance; Exponential and Non-exponential Decay	209
10.7	Quantum Zeno Effect	210
10.8	Resonance Cross Section	215
10.9	Unitarity and Super-Radiance	217
10.10	Angular Momentum and Parity	218
10.11	Narrow Resonance as a Compound System	219
10.12	Interference of Resonance and Potential Scattering	221
<b>11</b>	<b>Towards Relativistic Quantum Mechanics</b>	225
11.1	Limitations of the Approach	225
11.2	Relativistic Units	226
11.3	Lorentz Transformation	226
11.4	Energy and Momentum	227
11.5	Tensors and Notations	229
11.6	Klein–Gordon Equation	231
11.7	Current Conservation	233

11.8	Particles and Antiparticles	234
11.9	Electromagnetic Field	236
11.10	Minimal Electromagnetic Coupling	237
11.11	Photoabsorption at Higher Energies	240
11.12	Nuclear Photoeffect	242
11.13	Estimates of Processes in QED	244
<b>12</b>	<b>Dirac Equation: Formalism</b>	249
12.1	Introducing the Dirac Equation	249
12.2	Covariant Form and Algebra	251
12.3	Current	253
12.4	Charge Conjugation	254
12.5	Relativistic Transformations	256
12.6	Spin Operator	258
12.7	Bilinear Covariants	260
<b>13</b>	<b>Dirac Equation: Solutions</b>	265
13.1	Free Motion	265
13.2	Dirac Sea	266
13.3	Explicit Solutions	267
13.4	Complete Set of Solutions	270
13.5	Pauli Equation	273
13.6	Second Order Effects	274
13.7	Central Field	276
13.8	Coulomb Field	279
13.9	Static Uniform Magnetic Field	283
<b>14</b>	<b>Discrete Symmetries, Neutrino and Kaons</b>	285
14.1	Parity Transformation for a Dirac Particle	285
14.2	Time-Reversal Transformation	287
14.3	<i>CPT</i> Transformation	288
14.4	Massless Particles	289
14.5	Neutrinos in the Massless Limit	291
14.6	Parity Non-conservation Revisited	293
14.7	Neutrino Oscillations	295
14.8	Majorana Neutrinos	297
14.9	Strangeness	299
14.10	Neutral Kaons and <i>CP</i> -parity	300
14.11	Neutral Kaons and Quantum Regeneration	303
<b>15</b>	<b>Identical Particles</b>	307
15.1	Indistinguishable Particles	307
15.2	Permutational Symmetry	308
15.3	Bosons and Fermions	310
15.4	Wave Functions of Noninteracting Particles	312
15.5	Two-Nucleon States	315
15.6	Scattering of Identical Particles	324

15.7	Intensity Interferometry	328
<b>16</b>	<b>Isospin</b>	331
16.1	Introducing Isospin	331
16.2	Isospin Invariance	333
16.3	Isospin of Many-Body Systems	334
16.4	Isospin and Space-Spin Symmetry	336
16.5	A Glimpse of a More General Picture	338
16.6	Relations between Cross Sections	340
<b>17</b>	<b>Secondary Quantization</b>	345
17.1	Occupation Number Representation	345
17.2	Introduction to Secondary Quantization	347
17.3	Bose-Statistics	348
17.4	Fermi-Statistics	350
17.5	Algebraic Relations	351
17.6	One-Body Operators	352
17.7	Two-Body Operators	356
17.8	Interparticle Interaction in the Plane-Wave Basis	357
17.9	Interparticle Interaction in a Finite System	359
<b>18</b>	<b>Atomic and Nuclear Configurations</b>	363
18.1	Independent Particle Approximation	363
18.2	Adding Rotational Invariance	364
18.3	Many-Particle Configurations	366
18.4	Exchange Interaction	370
18.5	Two-Electron System	372
18.6	Helium Atom: Optical Spectrum	375
18.7	Hund's Rules	376
18.8	Particle-Hole Symmetry	378
18.9	Shell Structure	380
<b>19</b>	<b>Fermions</b>	383
19.1	Ideal Fermi-Gas	383
19.2	Spin Paramagnetism	388
19.3	Orbital Diamagnetism	391
19.4	Introducing Mean Field	393
19.5	Statistical Model	395
19.6	Screening in the Electron Gas	398
19.7	Hartree-Fock Approximation	399
19.8	Spatially Uniform System	402
19.9	Coulomb Gas	404
19.10	Density Functional Theory	406
<b>20</b>	<b>Collective Excitations</b>	409
20.1	Linear Chain	409
20.2	Phonons	413

20.3	Phonon Modes	415
20.4	Spin Waves	418
20.5	Particle–Hole Excitations	424
20.6	Density Fluctuations	426
20.7	Random Phase Approximation	428
20.8	Electron–Phonon Interaction	429
<b>21</b>	<b>Bosons</b>	433
21.1	Bose–Einstein Condensation	433
21.2	Condensate as a Reservoir; Chemical Potential	435
21.3	Weakly Non-ideal Gas	437
21.4	Phonons	439
21.5	Superfluidity	441
21.6	Canonical Transformation	442
21.7	Phonons as Density Waves	445
21.8	Local Density Approximation	447
21.9	Non-uniform Gas	450
<b>22</b>	<b>Fermion Pairing and Superconductivity</b>	453
22.1	Pairing	453
22.2	Pairs and Seniority	455
22.3	Multipole Moments in the Seniority Scheme	458
22.4	Degenerate Model and Quasispin	459
22.5	Canonical Transformation	462
22.6	BCS Theory and Trial Wave Function	466
22.7	Energy Minimization	467
22.8	Energy Gap	469
22.9	Excitation Spectrum	473
22.10	Condensation Energy	477
22.11	Transition Amplitudes	478
<b>23</b>	<b>Density Matrix</b>	481
23.1	Mixed States and Density Matrix	481
23.2	Properties of the Density Matrix	482
23.3	Thermal Equilibrium	486
23.4	Polarization Density Matrix	489
23.5	Application of Scattering	493
23.6	Ensemble Entropy	496
23.7	Evolution of the Density Matrix	498
23.8	Linear Response Revisited	500
23.9	Electric Conductivity	501
<b>24</b>	<b>Quantum Chaos</b>	505
24.1	Classical and Quantum Chaos	505
24.2	Local Spectral Statistics: Poisson Distribution	508
24.3	Gaussian Orthogonal Ensemble	512
24.4	Level Spacing Distribution	514

24.5	GOE and Information	517
24.6	Universality Classes	518
24.7	Semicircle Law	521
24.8	Chaotic Eigenfunctions	527
24.9	Complexity and Information Entropy	531
24.10	Porter-Thomas and Related Distributions	533
<b>25</b>	<b>Quantum Entanglement</b>	535
25.1	Entanglement	535
25.2	Teleportation	536
25.3	Mathematics of Entanglement	538
25.4	Quantum Bell Inequalities	541
25.5	EPR(B) Paradox and Hidden Variables	543
25.6	Experimental Tests	546
25.7	Decoherence and Measurement Paradox	547
<b>References</b>		551
<b>Further Reading</b>		555
<b>Index</b>		563

