

Contents

1	WAVE FUNCTION	7
1.1	Probability Theory	8
1.1.1	Mean, Average, Expectation Value	8
1.1.2	Average of a Function	10
1.1.3	Mean, Median, Mode	10
1.1.4	Standard Deviation and Uncertainty	11
1.1.5	Probability Density	14
1.2	Postulates of Quantum Mechanics	14
1.3	Conservation of Probability (Continuity Equation)	19
1.3.1	Conservation of Charge	19
1.3.2	Conservation of Probability	22
1.4	Interpretation of the Wave Function	23
1.5	Expectation Value in Quantum Mechanics	24
1.6	Operators	24
1.7	Commutation Relations	27
1.8	Problems	32
1.9	Answers	33
2	DIFFERENTIAL EQUATIONS	35
2.1	Ordinary Differential Equations	35
2.1.1	Second Order, Homogeneous, Linear, Ordinary Differential Equations with Constant Coefficients	36
2.1.2	Inhomogeneous Equation	39
2.2	Partial Differential Equations	42
2.3	Properties of Separable Solutions	44
2.3.1	General Solutions	44
2.3.2	Stationary States	44
2.3.3	Definite Total Energy	45

2.3.4	Alternating Parity	46
2.3.5	Nodes	46
2.3.6	Complete Orthonormal Sets of Functions	46
2.3.7	Time-dependent Coefficients	49
2.4	Problems	50
2.5	Answers	51
3	INFINITE 1-DIMENSIONAL BOX	53
3.1	Energy Levels	54
3.2	Wave Function	57
3.3	Problems	63
3.4	Answers	64
4	POSTULATES OF QUANTUM MECHANICS	65
4.1	Mathematical Preliminaries	65
4.1.1	Hermitian Operators	65
4.1.2	Eigenvalue Equations	66
4.2	Postulate 4	67
4.3	Expansion Postulate	68
4.4	Measurement Postulate	69
4.5	Reduction Postulate	70
4.6	Summary of Postulates of Quantum Mechanics (Simple Version)	71
4.7	Problems	74
4.8	Answers	75
I	1-DIMENSIONAL PROBLEMS	77
5	Bound States	79
5.1	Boundary Conditions	80
5.2	Finite 1-dimensional Well	81
5.2.1	Regions I and III With Real Wave Number	82
5.2.2	Region II	83
5.2.3	Matching Boundary Conditions	84
5.2.4	Energy Levels	87
5.2.5	Strong and Weak Potentials	88
5.3	Power Series Solution of ODEs	89
5.3.1	Use of Recurrence Relation	91
5.4	Harmonic Oscillator	92

5.5	Algebraic Solution for Harmonic Oscillator	100
5.5.1	Further Algebraic Results for Harmonic Oscillator . .	108
6	SCATTERING STATES	113
6.1	Free Particle	113
6.1.1	Group Velocity and Phase Velocity	117
6.2	Transmission and Reflection	119
6.2.1	Alternative Approach	120
6.3	Step Potential	121
6.4	Finite Potential Barrier	124
6.5	Quantum Description of a Colliding Particle	126
6.5.1	Expansion Coefficients	128
6.5.2	Time Dependence	129
6.5.3	Moving Particle	130
6.5.4	Wave Packet Uncertainty	131
7	FEW-BODY BOUND STATE PROBLEM	133
7.1	2-Body Problem	133
7.1.1	Classical 2-Body Problem	134
7.1.2	Quantum 2-Body Problem	137
7.2	3-Body Problem	139
II	3-DIMENSIONAL PROBLEMS	141
8	3-DIMENSIONAL SCHRÖDINGER EQUATION	143
8.1	Angular Equations	144
8.2	Radial Equation	147
8.3	Bessel's Differential Equation	148
8.3.1	Hankel Functions	150
9	HYDROGEN-LIKE ATOMS	153
9.1	Laguerre Associated Differential Equation	153
9.2	Degeneracy	157
10	ANGULAR MOMENTUM	159
10.1	Orbital Angular Momentum	159
10.1.1	Uncertainty Principle	162
10.2	Zeeman Effect	163
10.3	Algebraic Method	164

10.4 Spin	165
10.4.1 Spin $\frac{1}{2}$	166
10.4.2 Spin-Orbit Coupling	167
10.5 Addition of Angular Momentum	169
10.5.1 Wave Functions for Singlet and Triplet Spin States . .	171
10.5.2 Clebsch-Gordon Coefficients	172
10.6 Total Angular Momentum	172
10.6.1 LS and jj Coupling	173
11 SHELL MODELS	177
11.1 Atomic Shell Model	177
11.1.1 Degenerate Shell Model	177
11.1.2 Non-Degenerate Shell Model	178
11.1.3 Non-Degenerate Model with Surface Effects	178
11.1.4 Spectra	179
11.2 Hartree-Fock Self Consistent Field Method	180
11.3 Nuclear Shell Model	181
11.3.1 Nuclear Spin	181
11.4 Quark Shell Model	182
12 DIRAC NOTATION	183
12.1 Finite Vector Spaces	183
12.1.1 Real Vector Space	183
12.1.2 Complex Vector Space	185
12.1.3 Matrix Representation of Vectors	188
12.1.4 One-Forms	188
12.2 Infinite Vector Spaces	189
12.3 Operators and Matrices	191
12.3.1 Matrix Elements	191
12.3.2 Hermitian Conjugate	194
12.3.3 Hermitian Operators	195
12.3.4 Expectation Values and Transition Amplitudes	197
12.4 Postulates of Quantum Mechanics (Fancy Version)	198
12.5 Uncertainty Principle	198
13 TIME-INDEPENDENT PERTURBATION THEORY, HY- DROGEN ATOM, POSITRONIUM, STRUCTURE OF HADRONS	201
13.1 Non-degenerate Perturbation Theory	204
13.2 Degenerate Perturbation Theory	208

13.2.1	Two-fold Degeneracy	209
13.2.2	Another Approach	211
13.2.3	Higher Order Degeneracies	212
13.3	Fine Structure of Hydrogen	212
13.3.1	1-Body Relativistic Correction	212
13.3.2	Two-Body Relativistic Correction	216
13.3.3	Spin-Orbit Coupling	217
13.4	Zeeman effect	220
13.5	Stark effect	221
13.6	Hyperfine splitting	221
13.7	Lamb shift	221
13.8	Positronium and Muonium	221
13.9	Quark Model of Hadrons	221
14	VARIATIONAL PRINCIPLE, HELIUM ATOM, MOLECULES	223
14.1	Variational Principle	223
14.2	Helium Atom	223
14.3	Molecules	223
15	WKB APPROXIMATION, NUCLEAR ALPHA DECAY	225
15.1	Generalized Wave Functions	225
15.2	Finite Potential Barrier	230
15.3	Gamow's Theory of Alpha Decay	231
16	TIME-DEPENDENT PERTURBATION THEORY, LASERS	235
16.1	Equivalent Schrödinger Equation	236
16.2	Dyson Equation	240
16.3	Constant Perturbation	241
16.4	Harmonic Perturbation	244
16.5	Photon Absorption	247
16.5.1	Radiation Bath	247
16.6	Photon Emission	249
16.7	Selection Rules	249
16.8	Lasers	250
17	SCATTERING, NUCLEAR REACTIONS	251
17.1	Cross Section	251
17.2	Scattering Amplitude	252
17.2.1	Calculation of c_l	255

17.3 Phase Shift	257
17.4 Integral Scattering Theory	259
17.4.1 Lippman-Schwinger Equation	259
17.4.2 Scattering Amplitude	261
17.4.3 Born Approximation	262
17.5 Nuclear Reactions	264
18 SOLIDS AND QUANTUM STATISTICS	265
18.1 Solids	265
18.2 Quantum Statistics	265
19 SUPERCONDUCTIVITY	267
20 ELEMENTARY PARTICLES	269
21 chapter 1 problems	271
21.1 Problems	271
21.2 Answers	272
21.3 Solutions	273
22 chapter 2 problems	281
22.1 Problems	281
22.2 Answers	282
22.3 Solutions	283
23 chapter 3 problems	287
23.1 Problems	287
23.2 Answers	288
23.3 Solutions	289
24 chapter 4 problems	291
24.1 Problems	291
24.2 Answers	292
24.3 Solutions	293