CONTENTS

CHAPTER 1. HISTORICAL INTRODUCTION 1

1–1 Planck's theory of blackbody radiation 1
1–2 Einstein's photon theory of light 7
1–3 Bohr's theory of the hydrogen atom 11
1–4 Sommerfeld's generalization and the old quantum theory . . 17
1–5 De Broglie's wave theory of matter 26
1–6 The development of quantum mechanics 30

CHAPTER 2. THE SCHRÖDINGER EQUATION AND ITS MATHEMATICAL IMPLICATION 35

2–1 Relations between the law of mechanics of a particle and the law of wave propagation 35
2–2 The equation of motion of a wave packet 42
2–3 Mathematical formulation of quantum mechanics—the Schrödinger equation 45
2–4 The statistical interpretation of the Schrödinger equation . . 48
2–5 The uncertainty relation 52
2–6 Newton's second law of motion as a special case of quantum mechanics 54
2–7 Quantum mechanics and the Hamiltonian theory 58
2–8 Normalization. The probability current density 62
2–9 The general solution of the time-dependent Schrödinger equation 65
2–10 Summary 68

CHAPTER 3. THE FREE PARTICLE 71

3–1 The general solution in classical mechanics 71
3–2 The general solution in quantum mechanics 71
3–3 Classical mechanics as a special case of quantum mechanics . . 73
3–4 Explanation of a quantum phenomenon: the wave property of matter 77

CHAPTER 4. THE LINEAR HARMONIC OSCILLATOR 81

4–1 The general solution in classical mechanics 81
4–2 The general solution in quantum mechanics 81
4–3 Classical mechanics as a special case of quantum mechanics . . 88
4–4 Explanation of a quantum phenomenon: the quantization of energy 95

CHAPTER 5. ONE-DIMENSIONAL POTENTIAL BARRIER PROBLEMS . . 99
5–1 The potential well problem 99
5–2 The potential barrier problem 104
5–3 Explanation of a quantum phenomenon: the penetration of potential barrier in radioactive decay 108

CHAPTER 6. THE PHYSICAL MEANING OF QUANTUM MECHANICS . . 112
6–1 Critiques of the classical concepts in mechanics. Heisenberg's uncertainty principle 112
6–2 Quantum-mechanical description of physical processes. The law of causality 125
6–3 Explanation of the quantum phenomena 131
A. The wave property of matter 132
B. The quantization of energy 133
C. The penetration of potential barrier 134
6–4 Concluding remarks 136

CHAPTER 7. GENERAL METHODS FOR ONE-DIMENSIONAL PROBLEMS . 140
7–1 Qualitative properties of the one-dimensional wave function . . 140
7–2 Approximate solution by the WKB method 143

CHAPTER 8. THREE-DIMENSIONAL PROBLEMS 150
8–1 The space rotator 150
8–2 Central force problems 157
8–3 The hydrogen atom 162
8–4 The positronium, mesic atoms, ionized atoms, alkali atoms, and exciton 175

CHAPTER 9. THE THREE-DIMENSIONAL HARMONIC OSCILLATOR . . . 181
9–1 Solution in rectangular coordinates 181
9–2 Solution in cylindrical coordinates 184
9–3 Solution in spherical coordinates 190
9–4 Orthogonality of the wave functions 195

CHAPTER 10. TIME-INDEPENDENT PERTURBATION THEORY 199
10–1 Perturbation theory for nondegenerate levels 199
10–2 Perturbation theory for degenerate levels 207
10–3 A generalized perturbation theory 213
10–4 The Stark effect 217
A. The old quantum theory 218
B. The nondegenerate perturbation method 220
C. The degenerate perturbation method 223
D. The generalized perturbation method 225

CHAPTER 11. TIME-DEPENDENT PERTURBATION THEORY 231
11–1 General theory of time-dependent perturbation 231
11–2 The sudden and the adiabatic approximations 244
11–3 Transition to continuous states 256
11–4 The Rutherford scattering 267
A. The classical theory 268
B. The time-dependent perturbation theory 270
C. The time-independent perturbation theory 275
11–5 The radiation processes 280
A. The perturbation treatment of the radiative transitions . 281
B. Transition probabilities; selection, intensity, and polarization rules 286
C. The spontaneous emission 293

CHAPTER 12. GENERAL FORMULATION OF QUANTUM MECHANICS AND ITS APPLICATIONS 297
12–1 Dynamical quantities represented by operators 297
12–2 The algebra of operators 306
12–3 Angular momentum in quantum mechanics 311
12–4 Position eigenfunctions and the principle of superposition . . 315
12–5 Equations of motion in the operator form 319
12–6 General formulation of quantum mechanics 322
12–7 Classical mechanics as a limiting case of quantum mechanics . 332
12–8 Quantization of many-particle systems 334
12–9 Quantization of the motion of a rigid body 339
A. The plane rotator 339
B. The rigid rotator 341
C. The symmetric top 342
12–10 Quantization of the motion of a charged particle in a magnetic field 347
12–11 Quantization of the radiation field 352
12–12 Quantization of the matter wave 357

CHAPTER 13. MATRIX MECHANICS 361
13–1 Introduction. 362
13–2 Matrix formulation as a substitute for classical mechanics . 363
13–3 The commutator of momentum and coordinate 365

TABLE OF PHYSICAL CONSTANTS 369

INDEX 371