

CONTENTS

PREFACE	xvii
PHYSICAL CONSTANTS	xix
1 LAGRANGIAN AND HAMILTONIAN FORMULATIONS	1
1 Introduction / 1	
2 Newton's Law Approach / 2	
3 Lagrangian Formulation / 3	
4 Hamiltonian Formulation / 6	
5 Variational Principles and Virtual Displacements / 8	
2 CENTRAL FORCES	10
1 Introduction / 10	
2 Action and Reaction / 11	
3 Two-Particle Central Force Motion / 12	
4 Equations and Orbits of the Motion / 15	

- 5 Bound and Closed Orbits / 19
- 6 Open Orbits and Scattering / 22
- 7 Three-Body Problem / 24

3 RIGID BODIES

28

- 1 Introduction / 28
- 2 Nature and Orientation of a Rigid Body / 29
- 3 Rotation Matrices / 32
- 4 Vector and Tensor Transformations / 33
- 5 Parity / 34
- 6 Two-Dimensional Representation of Rotations / 35
- 7 Rotating Coordinate Systems and Coriolis Force / 36
- 8 Rotating Bodies / 38

4 OSCILLATIONS AND VIBRATIONS

42

- 1 Introduction / 42
- 2 Molecular Vibrations / 43
- 3 Rigid Body / 43
- 4 Normal Modes / 45
- 5 Triatomic Molecule / 46
- 6 Linear Chain of N Atoms / 48
- 7 Dispersion Relations / 51
- 8 Diatomic Linear Chain / 52
- 9 Vibrating Solids / 54
- 10 Molecular Rotations / 55
- 11 Molecular Vibrational Spectroscopy / 57

5 CANONICAL TRANSFORMATIONS

59

- 1 Introduction / 59
- 2 Nature of the Canonical Transformation / 60
- 3 Harmonic Oscillator / 61
- 4 Hamilton–Jacobi Equation / 62
- 5 Action–Angle Variables / 64
- 6 Poisson Brackets / 66

6 NON-LINEAR DYNAMICS AND CHAOS**68**

- 1 Introduction / 68
- 2 Perturbation Theory / 69
- 3 Harmonic Oscillator in Phase Space / 70
- 4 System Trajectories on N -Tori / 71
- 5 Stability of Perturbed Orbits and Chaos / 72
- 6 Logistic Equation or Quadratic Iterator / 73
- 7 Characteristics and Constants of Chaos / 78
- 8 Chaos in Different Systems / 81

7 RELATIVITY**87**

- 1 Introduction / 87
- 2 Newtonian Mechanics / 88
- 3 Constancy of Speed of Light / 88
- 4 Lorentz Transformation / 89
- 5 Past and Future / 91
- 6 Lorentz Contraction and Time Dilatation / 94
- 7 Doppler Shift / 95
- 8 Newton's Law / 96
- 9 Scalar Products and Invariants / 97
- 10 More General Transformations / 98

8 THERMODYNAMICS**101**

- 1 Introduction / 102
- 2 Exact and Inexact Differentials / 102
- 3 Laws of Thermodynamics / 103
- 4 Heat Engine and Carnot Cycle / 105
- 5 Internal Energy, Enthalpy, and Free Energies / 107
- 6 Maxwell Relations / 108
- 7 Gibbs Phase Rule / 109
- 8 Changes of Phase / 110
- 9 Specific Heat of Ideal Gas / 112
- 10 Adiabatic Gas Law / 113
- 11 Specific Heat of Solids / 114

- 12 Thermoelectric and Thermomagnetic Effects / 116
- 13 Negative Temperatures / 121
- 14 Statistical Mechanics / 121

9 STATISTICAL MECHANICS AND DISTRIBUTION FUNCTIONS

123

- 1 Introduction / 123
- 2 Microcanonical Ensemble / 125
- 3 Canonical Ensemble / 125
- 4 Grand Canonical Ensemble / 127
- 5 Thermodynamics / 129
- 6 Paramagnetism / 130
- 7 Entropy and Adiabatic Demagnetization / 132
- 8 Maxwell Distribution / 133
- 9 Classical and Quantum Statistics / 134
- 10 Distribution Functions / 137
- 11 Photon Statistics / 138
- 12 Ortho-Para Statistics / 140

10 ELECTROSTATICS AND MAGNETOSTATICS

142

- 1 Introduction / 143
- 2 Electric and Magnetic Fields / 143
- 3 Maxwell's Equations / 144
- 4 Electromagnetic Potentials / 145
- 5 Dielectric Constant and Permeability / 146
- 6 Boundary Conditions at Interfaces between Media / 00147
- 7 Sources of Electric Field / 148
- 8 Sources of Magnetic Field / 150
- 9 Electrostatics / 152
- 10 Boundary Conditions at Surfaces / 153
- 11 Solving Potential Problems / 154
- 12 Tesseral and Spherical Harmonics / 155
- 13 Magnetostatics / 156
- 14 Faraday's Law / 159

11	MULTIPOLES AND MEDIA	160
1	Introduction / 160	
2	Electric Multipoles / 161	
3	Electric Dipole Fields / 164	
4	Energy and Torque / 164	
5	Magnetic Multipoles / 166	
6	Magnetic Moments / 167	
7	Dielectric Constant and Permeability / 168	
8	Ellipsoids in Electric and Magnetic Fields / 170	
9	Nuclear and Atomic Multipoles / 174	
12	RELATIVISTIC ELECTRODYNAMICS	176
1	Introduction / 176	
2	Electromagnetic Field Tensor / 177	
3	Invariants / 179	
4	Field Tensor and Potentials / 180	
5	Gauge Transformations / 182	
6	Motion of Charge in Electromagnetic Fields / 183	
7	Perpendicular Fields / 184	
8	Adiabatic Invariants / 186	
13	WAVE PROPAGATION	188
1	Introduction / 188	
2	Plane Waves / 189	
3	Reflection and Refraction / 191	
4	Reflection, Refraction, and Transmission at Oblique Incidence / 193	
5	Polarization / 195	
6	Absorption and Dispersion / 196	
7	Conducting Media / 197	
8	Guided Waves / 200	
9	Modulated Waves / 201	
10	Solitons / 202	

14 OPTICS	206
1 Introduction / 206	
2 Index of Refraction / 207	
3 Lenses / 207	
4 Mirrors / 209	
5 Polarization / 210	
6 Interference and Diffraction / 212	
7 Interference / 213	
8 Single, Double, and Multiple Slits / 215	
15 RADIATION	219
1 Introduction / 219	
2 Radiating Charge and Current Distributions / 220	
3 Radiation Zones / 221	
4 Electric Dipole Radiation / 222	
5 Charge in Uniform Motion / 224	
6 Accelerated Charge / 226	
7 Slowly Moving Accelerated Charge / 226	
8 Relativistically Accelerated Charge / 227	
9 Cherenkov Radiation / 230	
10 Transition Radiation / 231	
16 COLLISIONS	233
1 Introduction / 233	
2 Coulomb Collision / 234	
3 Collisions with Nuclei / 237	
4 Bremsstrahlung / 239	
5 Thomson Scattering / 240	
17 ANGULAR MOMENTUM	242
1 Introduction / 242	
2 Linear and Angular Momentum / 243	
3 Momentum Operators / 244	
4 Orbital and Spin Angular Momentum / 246	

- 5 Spin–Orbit Interaction / 248
- 6 Wave Functions and Clebsch Gordan Coefficients / 249
- 7 Irreducible Tensors / 251

18 MATRIX FORMULATION OF QUANTUM MECHANICS 255

- 1 Introduction / 255
- 2 Angular Momentum Matrices / 256
- 3 Addition of Angular Momentum / 258
- 4 Zeeman Effect of Hydrogen Atom / 259
- 5 General Hamiltonian Matrix / 262

19 SCHRÖDINGER EQUATION 264

- 1 Introduction / 264
- 2 The Hamiltonian / 265
- 3 Laplacian Operator and Radial Equation / 266
- 4 Three-Dimensional Square Well / 267
- 5 Infinite Square Well / 269
- 6 Three-Dimensional Harmonic Oscillator / 270

20 ONE-DIMENSIONAL QUANTUM SYSTEMS 275

- 1 Introduction / 275
- 2 Schrödinger Equation / 276
- 3 Reflection at the Potential Step / 278
- 4 Transmission Past the Potential Step / 279
- 5 Potential Barrier / 281
- 6 Square Well Potential / 283
- 7 Infinite Square Well / 288

21 ATOMS 290

- 1 Introduction / 290
- 2 The Hydrogen Atom / 291
- 3 Spin–Orbit Interaction / 295
- 4 The Helium Atom / 296
- 5 Energies and Sizes of Atoms / 299

6 Hartree–Fock Method / 304

22 PERTURBATION THEORY 306

- 1 Introduction / 306
- 2 Power Series Expansion / 307
- 3 Time Independent Perturbations / 308
- 4 Hydrogen Atom Zeeman Effect / 309
- 5 Degenerate Perturbation Theory / 312
- 6 Time Dependent Perturbations / 313
- 7 Transition Probability / 316
- 8 Scattering / 317

23 FLUIDS AND SOLIDS 319

- 1 Introduction / 319
- 2 Gases / 320
- 3 Phase Transitions / 322
- 4 Liquid State and Fluctuations / 323
- 5 Diffusion / 326
- 6 Structure of Solids / 327
- 7 Close Packing / 328
- 8 Direct and Reciprocal Lattice / 331
- 9 Crystal Structure Determination / 332
- 10 Wigner–Seitz Cell / 334
- 11 Phonons and Other Particles / 336
- 12 Superconductivity / 338

24 CONDUCTION IN SOLIDS 340

- 1 Introduction / 340
- 2 Electron Transport Theories / 342
- 3 Electrical Conductivity / 343
- 4 AC Electrical Conductivity / 344
- 5 Resistivity / 345
- 6 Thermal Conductivity / 346
- 7 Fermi Surface / 347

- 8 Energy Bands in Two Dimensions / 354
- 9 Semiconductors / 357
- 10 Hall Effect / 360

25 NUCLEI**363**

- 1 Introduction / 363
- 2 Fundamental Forces / 364
- 3 Size of the Nucleus / 366
- 4 Binding Energy / 367
- 5 Shell Model / 369
- 6 Radioactive Decay / 371
- 7 Helicity and Parity Non-Conservation / 375
- 8 Mössbauer Effect / 376
- 9 Carbon Dating and the Carbon Cycle / 377

26 ELEMENTARY PARTICLES**379**

- 1 Introduction / 379
- 2 Characteristics of the Fundamental Forces / 380
- 3 Particle Characteristics / 383
- 4 Three-Quark Model / 385
- 5 Conservation Laws and Reactions / 393
- 6 Leptons / 395
- 7 Color, Charm, Beauty, and Truth / 395

27 MATHEMATICAL PHYSICS: TENSORS AND MATRICES , 399

- 1 Introduction / 400
- 2 Vector Relations / 400
- 3 Coordinate Systems / 402
- 4 Determinants / 407
- 5 Matrices / 408
- 6 Pauli Matrices and Spinors / 412
- 7 Tensors / 413
- 8 Infinite Series / 415
- 9 Fourier Series / 416

- 10 Fourier Transforms / 418
- 11 Integral Transforms and Equations / 421
- 12 Complex Variables / 425
- 13 Contour Integration / 427
- 14 Group Theory / 430
- 15 Monte Carlo Method / 436

28 MATHEMATICAL PHYSICS: DIFFERENTIAL EQUATIONS AND ORTHOGONAL FUNCTIONS 437

- 1 Introduction / 437
- 2 First-Order Differential Equations / 438
- 3 Second-Order Differential Equations / 439
- 4 Laplace and Helmholtz Equations / 447
- 5 Bessel Functions / 450
- 6 Legendre Polynomials / 457
- 7 Spherical Harmonics / 459
- 8 Gamma and Related Functions / 462
- 9 Delta Functions / 467
- 10 Green's Functions / 469

29 ENTANGLEMENT AND QUANTUM COMPUTING 471

- 1 Introduction / 471
- 2 Unitary Transformations of Qubits / 472
- 3 Entangled States / 476
- 4 Testing for Entanglement / 479
- 5 Factoring Large Numbers Classically / 482
- 6 Factoring Large Numbers with a Quantum Computer / 485
- 7 Implementing Quantum Computers / 489

BIBLIOGRAPHY 491

INDEX 495