



# CONTENTS

<b>PREFACE</b> .....	vii
<b>CHAPTER 1 SURVEY OF THE ELEMENTARY PRINCIPLES</b>	<b>1</b>
1-1 Mechanics of a particle .....	1
1-2 Mechanics of a system of particles .....	5
1-3 Constraints .....	11
1-4 D'Alembert's principle and Lagrange's equations .....	17
1-5 Velocity-dependent potentials and the dissipation function .....	21
1-6 Simple applications of the Lagrangian formulation .....	25
<b>CHAPTER 2 VARIATIONAL PRINCIPLES AND LAGRANGE'S EQUATIONS</b>	<b>35</b>
2-1 Hamilton's principle .....	35
2-2 Some techniques of the calculus of variations .....	37
2-3 Derivation of Lagrange's equations from Hamilton's principle .....	43
2-4 Extension of Hamilton's principle to nonholonomic systems .....	45
2-5 Advantages of a variational principle formulation .....	51
2-6 Conservation theorems and symmetry properties .....	54
<b>CHAPTER 3 THE TWO-BODY CENTRAL FORCE PROBLEM</b>	<b>70</b>
3-1 Reduction to the equivalent one-body problem .....	70
3-2 The equations of motion and first integrals .....	71
3-3 The equivalent one-dimensional problem, and classification of orbits ..	77
3-4 The virial theorem .....	82
3-5 The differential equation for the orbit, and integrable power-law potentials .....	85
3-6 Conditions for closed orbits (Bertrand's theorem) .....	90
3-7 The Kepler problem: Inverse square law of force .....	94
3-8 The motion in time in the Kepler problem .....	98
3-9 The Laplace-Runge-Lenz vector .....	102
3-10 Scattering in a central force field .....	105
3-11 Transformation of the scattering problem to laboratory coordinates ..	114

<b>CHAPTER 4</b>	<b>THE KINEMATICS OF RIGID BODY MOTION</b>	<b>128</b>
4-1	The independent coordinates of a rigid body .....	128
4-2	Orthogonal transformations .....	132
4-3	Formal properties of the transformation matrix .....	137
4-4	The Euler angles .....	143
4-5	The Cayley-Klein parameters and related quantities .....	148
4-6	Euler's theorem on the motion of a rigid body .....	158
4-7	Finite rotations .....	164
4-8	Infinitesimal rotations .....	166
4-9	Rate of change of a vector .....	174
4-10	The Coriolis force .....	177
<b>CHAPTER 5</b>	<b>THE RIGID BODY EQUATIONS OF MOTION</b>	<b>188</b>
5-1	Angular momentum and kinetic energy of motion about a point .....	188
5-2	Tensors and dyadics .....	192
5-3	The inertia tensor and the moment of inertia .....	195
5-4	The eigenvalues of the inertia tensor and the principal axis transformation .....	198
5-5	Methods of solving rigid body problems and the Euler equations of motion .....	203
5-6	Torque-free motion of a rigid body .....	205
5-7	The heavy symmetrical top with one point fixed .....	213
5-8	Precession of the equinoxes and of satellite orbits .....	225
5-9	Precession of systems of charges in a magnetic field .....	232
<b>CHAPTER 6</b>	<b>SMALL OSCILLATIONS</b>	<b>243</b>
6-1	Formulation of the problem .....	243
6-2	The eigenvalue equation and the principal axis transformation .....	246
6-3	Frequencies of free vibration, and normal coordinates .....	253
6-4	Free vibrations of a linear triatomic molecule .....	258
6-5	Forced vibrations and the effect of dissipative forces .....	263
<b>CHAPTER 7</b>	<b>SPECIAL RELATIVITY IN CLASSICAL MECHANICS</b>	<b>275</b>
7-1	The basic program of special relativity .....	275
7-2	The Lorentz transformation .....	278
7-3	Lorentz transformations in real four dimensional spaces .....	288
7-4	Further descriptions of the Lorentz transformation .....	293
7-5	Covariant four-dimensional formulations .....	298
7-6	The force and energy equations in relativistic mechanics .....	303
7-7	Relativistic kinematics of collisions and many-particle systems .....	309
7-8	The Lagrangian formulation of relativistic mechanics .....	320
7-9	Covariant Lagrangian formulations .....	326

<b>CHAPTER 8</b>	<b>THE HAMILTON EQUATIONS OF MOTION</b>	<b>339</b>
8-1	Legendre transformations and the Hamilton equations of motion . . . . .	339
8-2	Cyclic coordinates and conservation theorems . . . . .	347
8-3	Routh's procedure and oscillations about steady motion . . . . .	351
8-4	The Hamiltonian formulation of relativistic mechanics . . . . .	356
8-5	Derivation of Hamilton's equations from a variational principle . . . . .	362
8-6	The principle of least action . . . . .	365
<b>CHAPTER 9</b>	<b>CANONICAL TRANSFORMATIONS</b>	<b>378</b>
9-1	The equations of canonical transformation . . . . .	378
9-2	Examples of canonical transformations . . . . .	386
9-3	The symplectic approach to canonical transformations . . . . .	391
9-4	Poisson brackets and other canonical invariants . . . . .	397
9-5	Equations of motion, infinitesimal canonical transformations, and conservation theorems in the Poisson bracket formulation . . . . .	405
9-6	The angular momentum Poisson bracket relations . . . . .	416
9-7	Symmetry groups of mechanical systems . . . . .	420
9-8	Liouville's theorem . . . . .	426
<b>CHAPTER 10</b>	<b>HAMILTON-JACOBI THEORY</b>	<b>438</b>
10-1	The Hamilton-Jacobi equation for Hamilton's principal function . . . . .	438
10-2	The harmonic oscillator problem as an example of the Hamilton-Jacobi method . . . . .	442
10-3	The Hamilton-Jacobi equation for Hamilton's characteristic function . . . . .	445
10-4	Separation of variables in the Hamilton-Jacobi equation . . . . .	449
10-5	Action-angle variables in systems of one degree of freedom . . . . .	457
10-6	Action-angle variables for completely separable systems . . . . .	463
10-7	The Kepler problem in action-angle variables . . . . .	472
10-8	Hamilton-Jacobi theory, geometrical optics, and wave mechanics . . . . .	484
<b>CHAPTER 11</b>	<b>CANONICAL PERTURBATION THEORY</b>	<b>499</b>
11-1	Introduction . . . . .	499
11-2	Time-dependent perturbation (variation of constants) . . . . .	500
11-3	Illustrations of time-dependent perturbation theory . . . . .	506
11-4	Time-independent perturbation theory in first order with one degree of freedom . . . . .	515
11-5	Time-independent perturbation theory to higher order . . . . .	519
11-6	Specialized perturbation techniques in celestial and space mechanics . . . . .	527
11-7	Adiabatic invariants . . . . .	531

<b>CHAPTER 12</b>	<b>INTRODUCTION TO THE LAGRANGIAN AND HAMILTONIAN FORMULATIONS FOR CONTINUOUS SYSTEMS AND FIELDS</b>	<b>545</b>
12-1	The transition from a discrete to a continuous system .....	545
12-2	The Lagrangian formulation for continuous systems .....	548
12-3	The stress-energy tensor and conservation theorems .....	555
12-4	Hamiltonian formulation, Poisson brackets and the momentum representation .....	562
12-5	Relativistic field theory .....	570
12-6	Examples of relativistic field theories .....	575
12-7	Noether's theorem .....	588
<b>APPENDIXES</b>		<b>601</b>
A	Proof of Bertrand's Theorem .....	601
B	Euler Angles in Alternate Conventions .....	606
C	Transformation Properties of $d\Omega$ .....	611
D	The Staeckel Conditions for Separability of the Hamilton-Jacobi Equation .....	613
E	Lagrangian Formulation of the Acoustic Field in Gases .....	616
<b>BIBLIOGRAPHY</b>		<b>621</b>
<b>INDEX OF SYMBOLS</b>		<b>631</b>
<b>INDEX</b>		<b>643</b>