Contents

Chapter I Introduction, 10

- 1.1 Basic Concepts, 1
- 1.2 Scalar and Vector Quantities, 3
- 1.3 Properties of a Vector, 5
- 1.4 Moment of a Vector, 8
- 1.5 Angular Velocity Vector, 8
- 1.6 Derivative of a Vector, 10

Chapter 2 Kinematics, 13

- 2.1 Velocity and Acceleration, 13
- 2.2 Plane Motion (Radial and Transverse Components), 14
- 2.3 Tangential and Normal Components, 16
- 2.4 Plane Motion along a Rotating Curve (Relative Motion), 18
- 2.5 General Case of Space Motion, 20
- 2.6 Motion Relative to the Rotating Earth, 27

Chapter 3 Transformation of Coordinates, 29

- 3.1 Transformation of Displacements, 29
- 3.2 Transformation of Velocities, 31
- 3.3 Instantaneous Center, 32
- 3.4 Euler's Angles, 33
- 3.5 Transformation of Angular Velocities, 37

xii CONTENTS

Chapter 4 Particle Dynamics (Satellite Orbits), 44

- 4.1 Force and Momentum, 44
- 4.2 Impulse and Momentum, 45
- 4.3 Work and Energy, 47
- 4.4 Moment of Momentum, 49
- 4.5 Motion Under a Central Force, 52
- 4.6 The Two-Body Problem, 54
- 4.7 Orbits of Planets and Satellites, 56
- 4.8 Geometry of Conic Sections, 59
- 4.9 Orbit Established from Initial Conditions, 61
- 4.10 Satellite Launched with $\beta_0 = 0$, 63
- 4.11 Cotangential Transfer between Coplanar Circular Orbits, 66
- 4.12 Transfer between Coplanar Coaxial Elliptic Orbits, 70
- 4.13 Orbital Change Due to Impulsive Thrust, 71
- 4.14 Perturbation of Orbital Parameters, 79
- 4.15 Stability of Small Oscillations about a Circular Orbit, 81
- 4.16 Interception and Rendezvous, 83
- 4.17 Long-Range Ballistic Trajectories, 91
- 4.18 Effect of the Earth's Oblateness, 94

Chapter 5 Gyrodynamics, 101

- 5.1 Displacement of a Rigid Body, 101
- 5.2 Moment of Momentum of a Rigid Body (About a Fixed Point or the Moving Center of Mass), 102
- 5.3 Kinetic Energy of a Rigid Body, 105
- 5.4 Moment of Inertia about a Rotated Axis, 105
- 5.5 Principal Axes, 107
- 5.6 Euler's Moment Equation, 111
- 5.7 Euler's Equation for Principal Axes, 113
- 5.8 Body of Revolution with Zero External Moment (Body Coordinates),
- 5.9 Body of Revolution with Zero Moment, in Terms of Euler's Angles, 117
- 5.10 Unsymmetrical Body with Zero External Moment (Poinsot's Geometric Solution), 121
- 5.11 Unequal Moments of Inertia with Zero Moment (Analytical Solution), 126
- 5.12 Stability of Rotation about Principal Axes, 130
- 5.13 General Motion of a Symmetric Gyro or Top, 132
- 5.14 Steady Precession of a Symmetric Gyro or Top, 138
- 5.15 Precession and Nutation of the Earth's Polar Axis, 146
- 5.16 General Motion of a Rigid Body, 149

Chapter 6 Dynamics of Gyroscopic Instruments, 155

- 6.1 Small Oscillations of Gyros, 155
- 6.2 Oscillations About Gimbal Axes, 157

CONTENTS xiii

- 6.3 Gimbal Masses Included (Perturbation Technique), 163
- 6.4 The Gyrocompass, 170
- 6.5 Oscillation of the Gyrocompass, 171
- 6.6 The Rate Gyro, 178
- 6.7 The Integrating Gyro, 180
- 6.8 The Stable Platform, 180
- 6.9 The Three-Axis Platform, 183
- 6.10 Inertial Navigation, 186
- 6.11 Oscillation of Navigational Errors, 188

Chapter 7 Space Vehicle Motion, 194

- 7.1 General Equations in Body Coordinates, 194
- 7.2 Thrust Misalignment, 195
- 7.3 Rotations Referred to Inertial Coordinates, 198
- 7.4 Near Symmetric Body of Revolution with Zero Moment, 201
- 7.5 Despinning of Satellites, 208
- 7.6 Attitude Drift of Space Vehicles, 212
- 7.7 Variable Mass, 220
- 7.8 Jet Damping (Nonspinning Variable Mass Rocket), 221
- 7.9 Euler's Dynamical Equations for Spinning Rockets, 223
- 7.10 Angle of Attack of the Missile, 227
- 7.11 General Motion of Spinning Bodies with Varying Configuration and Mass, 230

Chapter 8 Performance and Optimization, 240

- 8.1 Performance of Single-Stage Rockets, 240
- 8.2 Optimization of Multistage Rockets, 246
- 8.3 Flight Trajectory Optimization, 248
- 8.4 Optimum Program for Propellant Utilization, 252
- 8.5 Gravity Turn, 257

Chapter 9 Generalized Theories of Mechanics, 261

- 9.1 Introduction, 261
- 9.2 System with Constraints, 261
- 9.3 Generalized Coordinates, 264
- 9.4 Holonomic and Nonholonomic Systems, 266
- 9.5 Principle of Virtual Work, 268
- 9.6 D'Alembert's Principle, 269
- 9.7 Hamilton's Principle, 270
- 9.8 Lagrange's Equation (Holonomic System), 272
- 9.9 Nonholonomic System, 279
- 9.10 Lagrange's Equation for Impulsive Forces, 282
- 9.11 Lagrange's Equations for Rotating Coordinates, 292
- 9.12 Missile Dynamic Analysis, 293

xiv CONTENTS

General References, 303

Appendix A Matrices, 305

Appendix B Dyadics, 307

Appendix C The Variational Calculus, 309

Index, 313