

Contents

| | | |
|----------|---|-----------------|
| | <i>List of Illustrations</i> | <i>page</i> vii |
| | <i>List of Tables</i> | xi |
| | <i>Preface</i> | xiii |
| | <i>Notation</i> | xvii |
| 1 | Introduction | 1 |
| | 1.1 Historical Background | 1 |
| | 1.2 Devices That Illustrate Principles of Analytical Dynamics | 5 |
| | 1.3 Scope of This Book | 8 |
| 2 | Mathematical Preliminaries | 10 |
| | 2.1 Linear Systems | 10 |
| | 2.2 Differential Geometry | 23 |
| | 2.3 Optimization | 28 |
| | 2.4 Exercises | 31 |
| 3 | Kinematics of Discrete Systems | 36 |
| | 3.1 Spherical Kinematics | 36 |
| | 3.2 Spatial Kinematics | 54 |
| | 3.3 Kinematic Chains | 69 |
| | 3.4 Kinematic Constraints and Degrees of Freedom | 76 |
| | 3.5 Exercises | 77 |
| 4 | Conservation Principles | 83 |
| | 4.1 The Newton-Euler Principle | 83 |
| | 4.2 Exercises | 99 |
| 5 | Zeroth-Order Variational Principles | 101 |
| | 5.1 Virtual Displacements | 101 |
| | 5.2 D'Alembert's Principle of Virtual Work | 101 |
| | 5.3 Hamilton's Principle of Least Action | 128 |

| | | |
|-----------|---|------------|
| 5.4 | Canonical Hamiltonian Formulation | 142 |
| 5.5 | Elimination of Multipliers | 145 |
| 5.6 | Exercises | 147 |
| 6 | First-Order Variational Principles | 151 |
| 6.1 | Virtual Velocities | 151 |
| 6.2 | Jourdain's Principle of Virtual Power | 151 |
| 6.3 | Kane's Formulation | 179 |
| 6.4 | Exercises | 185 |
| 7 | Second-Order Variational Principles | 188 |
| 7.1 | Virtual Accelerations | 188 |
| 7.2 | Gauss's Principle | 188 |
| 7.3 | Gauss's Principle of Least Constraint | 201 |
| 7.4 | Gibbs-Appell Formulation | 206 |
| 7.5 | Exercises | 211 |
| 8 | Dynamics in Task Space | 214 |
| 8.1 | Task Space Framework | 214 |
| 8.2 | Constrained Dynamics in Task Space | 227 |
| 8.3 | Exercises | 233 |
| 9 | Applications to Biomechanical Systems | 235 |
| 9.1 | Musculoskeletal and Neuromuscular Dynamics | 235 |
| 9.2 | Constrained Dynamics of Biomechanical Systems | 245 |
| 10 | Software for Analytical Dynamics | 263 |
| 10.1 | General Purpose Mathematical Software | 263 |
| 10.2 | Dedicated Multibody Dynamics Software | 268 |
| | Appendix Inclusion of Flexible Bodies | 269 |
| A.1 | Continuum Kinematics | 269 |
| A.2 | Continuum Dynamics | 270 |
| A.3 | Subsystem Assembly | 273 |
| | <i>References</i> | 275 |
| | <i>Index</i> | 279 |