ENGINEERING MECHANICS

DYNAMICS

FIFTEENTH EDITION IN SI UNITS

CONTENTS



12 Kinematics of a Particle 23

Chapter Objectives 23

- 12.1 Introduction 23
- **12.2** Rectilinear Kinematics: Continuous Motion 25
- **12.3** Rectilinear Kinematics: Erratic Motion 39
- **12.4** General Curvilinear Motion 52
- **12.5** Curvilinear Motion: Rectangular Components 54
- **12.6** Motion of a Projectile 59
- **12.7** Curvilinear Motion: Normal and Tangential Components 73
- *12.8 Curvilinear Motion: Cylindrical Components 87
- 12.9 Absolute Dependent Motion Analysis of Two Particles 101
- **12.10** Relative Motion of Two Particles Using Translating Axes 113

13

Kinetics of a Particle: Force and Acceleration 129

Chapter Objectives 129

- **13.1** Newton's Second Law of Motion 129
- **13.2** The Equation of Motion 132
- **13.3** Equation of Motion for a System of Particles 134
- **13.4** Equations of Motion: Rectangular Coordinates 136
- **13.5** Equations of Motion: Normal and Tangential Coordinates 154
- ***13.6** Equations of Motion: Cylindrical Coordinates 168
- ***13.7** Central-Force Motion and Space Mechanics 180



14 Kinetics of a Particle: Work and Energy 195

- Chapter Objectives 195
- **14.1** The Work of a Force 195
- 14.2 Principle of Work and Energy 200
- **14.3** Principle of Work and Energy for a System of Particles 202
- **14.4** Power and Efficiency 219
- 14.5 Conservative Forces and Potential Energy 228
- 14.6 Conservation of Energy 232



15 Kinetics of a Particle: Impulse and Momentum 251

Chapter Objectives 251

- **15.1** Principle of Linear Impulse and Momentum 251
- **15.2** Principle of Linear Impulse and Momentum for a System of Particles 254
- **15.3** Conservation of Linear Momentum for a System of Particles 267
- 15.4 Impact 279
- **15.5** Angular Momentum 294
- **15.6** Relation Between the Moment of a Force and Angular Momentum 295
- **15.7** Principle of Angular Impulse and Momentum 298
- **15.8** Bodies Subjected to a Mass Flow 309
- **15.9** Steady Flow of a Fluid Stream 311
- **15.10** Bodies that Lose or Gain Mass 315



16 Planar Kinematics of a Rigid Body 329

- Chapter Objectives 329
- **16.1** Planar Rigid-Body Motion 329
- 16.2 Translation 331
- **16.3** Rotation about a Fixed Axis 332
- ***16.4** Absolute Motion Analysis 348
- **16.5** Relative-Motion Analysis: Velocity 356
- 16.6 Instantaneous Center of Zero Velocity 369
- **16.7** Relative-Motion Analysis: Acceleration 381
- ***16.8** Relative-Motion Analysis using Rotating Axes 395



17 Planar Kinetics of a Rigid Body: Force and Acceleration 413

- Chapter Objectives 413
- **17.1** Mass Moment of Inertia 413
- **17.2** Planar Kinetic Equations of Motion 427
- **17.3** Equations of Motion: Translation 430
- **17.4** Equations of Motion: Rotation About a Fixed Axis 443
- 17.5 Equations of Motion: General Plane Motion 457



18 Planar Kinetics of a Rigid Body: Work and Energy 473

- Chapter Objectives 473
- **18.1** Kinetic Energy 473
- **18.2** The Work of a Force 476
- **18.3** The Work of a Couple Moment 478
- **18.4** Principle of Work and Energy 480
- **18.5** Conservation of Energy 495



Planar Kinetics of a Rigid Body: Impulse and Momentum 515

19

- Chapter Objectives 515
- **19.1** Linear and Angular Momentum 515
- **19.2** Principle of Impulse and Momentum 521
- **19.3** Conservation of Momentum 536
- ***19.4** Eccentric Impact 540



20 Three-Dimensional Kinematics of a Rigid Body 555

- Chapter Objectives 555
- **20.1** Rotation About a Fixed Point 555
- *20.2 The Time Derivative of a Vector Measured from a Fixed or Translating-Rotating System 558
- **20.3** General Motion 563
- ***20.4** Relative-Motion Analysis Using Translating and Rotating Axes 572



21 Three-Dimensional Kinetics of a Rigid Body 585

Chapter Objectives 585

- *21.1 Moments and Products of Inertia 585
- **21.2** Angular Momentum 595
- 21.3 Kinetic Energy 598
- ***21.4** Equations of Motion 606
- ***21.5** Gyroscopic Motion 620
- **21.6** Torque-Free Motion 626



22 Vibrations 637

Chapter Objectives 637

- **22.1** Undamped Free Vibration 637
- *22.2 Energy Methods 651
- *22.3 Undamped Forced Vibration 657
- ***22.4** Viscous Damped Free Vibration 661
- *22.5 Viscous Damped Forced Vibration 664
- *22.6 Electrical Circuit Analogs 667

Appendices

- A. Mathematical Expressions 676
- B. Vector Analysis 679
- C. The Chain Rule 685

Fundamental Problems Solutions and Answers 689

Review Problem Answers 711

Answers to Selected Problems 713

Index 727