Contents

Preface v

List of Symbols xv

Chapter 1 Introduction 3

1.1 What Is Mechanics? 3
1.2 Fundamental Concepts and Principles 3
1.3 Units 6
1.4 Method of Problem Solution 7
1.5 Numerical Accuracy 8

Chapter 2 Statics of Particles 10

FORCES IN A PLANE

2.1 Force on a Particle. Resultant of Two Forces 10
2.2 Addition of Concurrent Forces 12
2.3 Resolution of a Force into Components 12
2.4 Rectangular Components of a Force 18
2.5 Addition of Forces by Summing x and y Components 22
2.6 Equilibrium of a Particle 26
2.7 Newton's First Law of Motion 27
2.8 Problems Involving the Equilibrium of a Particle. Free-body Diagram 27

FORCES IN SPACE

2.9 Rectangular Components of a Force in Space 34
2.10 Components of Force and Components of Distance 37
2.11 Addition of Concurrent Forces in Space 39
2.12 Equilibrium of a Particle in Space 43

Chapter 3 Statics of Rigid Bodies in Two Dimensions 47

EQUIVALENT SYSTEMS OF FORCES

3.1 Rigid Bodies. External and Internal Forces 47
3.2 Principle of Transmissibility. Equivalent Forces 48
3.3 Two-dimensional Structures 50
3.4 Moment of a Force about an Axis 50
3.5 Varignon's Theorem 51
3.6 Moment of a Couple 56
3.7 Equivalent Couples 57
3.8 Addition of Couples 59

3.9 Resolution of a Given Force into a Force Acting at a Given Point and a Couple 59
3.10 Reduction of a System of Coplanar Forces to One Force and One Couple. Resultant of a System of Coplanar Forces. 64
3.11 Equivalent Systems of Coplanar Forces 66

EQUILIBRIUM OF RIGID BODIES

3.12 Rigid Body in Equilibrium 71
3.13 Free-body Diagram 72
3.14 Problems Involving the Equilibrium of a Rigid Body 74
3.15 Statically Indeterminate Reactions. Unstable Rigid Bodies . . . 76
3.16 Equilibrium of a Two-force Body 88
3.17 Equilibrium of a Three-force Body 89

GRAPHICAL METHODS

*3.18 A Graphical Method for the Reduction of a System of Forces . . . 92
*3.19 Resultant of a System of Forces by the Method of the Force Polygon and String Polygon 93
*3.20 Equilibrium of a Rigid Body by the Method of the Force Polygon and String Polygon 99

Chapter 4 Statics of Rigid Bodies in Three Dimensions 104

EQUIVALENT SYSTEMS OF FORCES

4.1 Moment of a Force about an Axis 104
4.2 Couples in Space 106
4.3 Resolution of a Given Force into a Force at *O* and a Couple . . . 113
4.4 Reduction of a System of Forces to One Force and One Couple . . 114

EQUILIBRIUM OF RIGID BODIES

4.5 Equilibrium of a Rigid Body in Space 121
4.6 Reactions at Supports and Connections 121

Chapter 5 Distributed Forces: Centroids and Centers of Gravity . 132

AREAS AND LINES

5.1 Center of Gravity of a Two-dimensional Body 132
5.2 Centroids of Areas and Lines 133
5.3 Composite Plates and Wires. 136
5.4 Determination of Centroids by Integration 143
5.5 Theorems of Pappus-Guldinus 144
*5.6 Distributed Loads on Beams 150
*5.7 Forces on Submerged Surfaces 151

VOLUMES

5.8 Center of Gravity of a Three-dimensional Body. Centroid of a Volume 157
5.9 Composite Bodies. 159
5.10 Determination of Centroids of Volumes by Integration 159

Chapter 6 Analysis of Structures 166

6.1 Internal Forces. Newton's Third Law 166

TRUSSES

6.2 Definition of a Truss 167
6.3 Simple Trusses 168
6.4 Analysis of Trusses by the Method of Joints 170
*6.5 Joints under Special Loading Conditions 173
6.6 Graphical Analysis of Trusses: Maxwell's Diagram 179
6.7 Analysis of Trusses by the Method of Sections 183
*6.8 Trusses Made of Several Simple Trusses 185

FRAMES AND MACHINES

6.9 Structures Containing Multiforce Members 192
6.10 Analysis of a Frame 192
6.11 Frames Consisting of Two or More Rigid Parts 193
6.12 Machines 205

Chapter 7 Forces in Beams and Cables 211

*7.1 Introduction. Internal Forces in Members 211

BEAMS

*7.2 Various Types of Loading and Support 215
*7.3 Shear and Bending Moment in a Beam 216
*7.4 Shear and Bending-moment Diagrams 218
*7.5 Relations between Load, Shear, and Bending Moment 224

CABLES

*7.6 Cables with Concentrated Loads 233
*7.7 Cables with Distributed Loads 235
*7.8 Parabolic Cable 235
*7.9 Catenary 243

Chapter 8 Friction 249

8.1 Introduction 249
8.2 The Laws of Dry Friction. Coefficients of Friction 249
8.3 Angles of Friction. 252
8.4 Problems Involving Dry Friction 253
8.5 Wedges. 263
8.6 Square-threaded Screws 264
*8.7 Journal Bearings. Axle Friction 270
*8.8 Thrust Bearings. Disk Friction 271
*8.9 Wheel Friction. Rolling Resistance 273
8.10 Belt Friction 279

Chapter 9 Distributed Forces: Moments of Inertia 287

MOMENTS OF INERTIA OF AREAS

9.1 Second Moment, or Moment of Inertia, of an Area 287
9.2 Determination of the Moment of Inertia of an Area by Integratition . 289
9.3 Polar Moment of Inertia. 291
9.4 Radius of Gyration of an Area 291

9.5 Parallel-axis Theorem 296
9.6 Moments of Inertia of Composite Areas 298
*9.7 Product of Inertia 307
*9.8 Principal Axes and Principal Moments of Inertia 309
*9.9 Mohr's Circle for Moments of Inertia 310

MOMENTS OF INERTIA OF MASSES

9.10 Moment of Inertia of a Mass 316
9.11 Parallel-axis Theorem 317
9.12 Moments of Inertia of Thin Plates 318
9.13 Determination of the Moment of Inertia of a Three-dimensional Body by Integration 320
9.14 Moments of Inertia of Composite Bodies 320

Chapter 10 Method of Virtual Work 329

*10.1 Work of a Force 329
*10.2 Principle of Virtual Work 331
*10.3 Applications of the Principle of Virtual Work 332
*10.4 Real Machines. Mechanical Efficiency 334
*10.5 Work of a Force during a Finite Displacement 341
*10.6 Potential Energy 343
*10.7 Potential Energy and Equilibrium 345
*10.8 Stability of Equilibrium 346

Chapter 11 Kinematics of Particles 353

11.1 Introduction to Dynamics 353

RECTILINEAR MOTION OF PARTICLES

11.2 Displacement, Velocity, and Acceleration 353
11.3 Determination of the Motion of a Particle 358
11.4 Uniform Rectilinear Motion 364
11.5 Uniformly Accelerated Rectilinear Motion 364
11.6 Motion of Several Particles 366
11.7 Graphical Solution of Rectilinear-motion Problems 371
*11.8 Other Graphical Methods 372

CURVILINEAR MOTION OF PARTICLES

11.9 Rectangular Components 377
11.10 Component Motions 380
11.11 Relative Motion 381
11.12 Tangential and Normal Components 387
*11.13 Radial and Transverse Components 389

Chapter 12 Kinetics of Particles: Force, Mass, and Acceleration . 396

12.1 Newton's Second Law of Motion 396
12.2 Systems of Units 397
12.3 Equations of Motion. Dynamic Equilibrium 400
12.4 Systems of Particles. D'Alembert's Principle 401
12.5 Motion of the Mass Center of a System of Particles 402

12.6 Rectilinear Motion of a Particle . . . 403
12.7 Curvilinear Motion of a Particle . . . 410
*12.8 Curvilinear Motion of a Particle. Radial and Transverse Components. 415
*12.9 Newton's Law of Gravitation . . . 417

Chapter 13 Kinetics of Particles: Work and Energy . . . 420

13.1 Introduction . . . 420
13.2 Work of a Force . . . 420
13.3 Kinetic Energy of a Particle. Principle of Work and Energy . . . 424
13.4 Applications of the Principle of Work and Energy . . . 425
13.5 Systems of Particles . . . 427
13.6 Potential Energy . . . 436
13.7 Conservation of Energy . . . 438
13.8 Power and Efficiency . . . 444

Chapter 14 Kinetics of Particles: Impulse and Momentum . . . 449

14.1 Principle of Impulse and Momentum . . . 449
14.2 Systems of Particles . . . 451
14.3 Impulsive Forces . . . 456
14.4 Conservation of Momentum . . . 456
14.5 Impact . . . 461
14.6 Direct Central Impact . . . 461
14.7 Oblique Central Impact . . . 464
14.8 Problems Involving Energy and Momentum . . . 465
*14.9 Variable Systems of Particles . . . 473
*14.10 Steady Stream of Particles . . . 473
*14.11 Systems Gaining or Losing Mass . . . 476

Chapter 15 Kinematics of Rigid Bodies . . . 484

15.1 Various Types of Plane Motion . . . 484
15.2 Translation . . . 486
15.3 Rotation . . . 487
15.4 Linear and Angular Velocity, Linear and Angular Acceleration in Rotation . . . 489
15.5 General Plane Motion . . . 494
15.6 Absolute and Relative Velocity in Plane Motion . . . 496
15.7 Instantaneous Center of Rotation in Plane Motion . . . 503
15.8 Absolute and Relative Acceleration in Plane Motion . . . 507
*15.9 Analysis of Plane Motion in Terms of a Parameter . . . 510
*15.10 Particle Moving on a Slab in Translation . . . 516
*15.11 Particle Moving on a Rotating Slab. Coriolis Acceleration . . . 517

Chapter 16 Kinetics of Rigid Bodies: Dynamic Equilibrium . . . 526

16.1 Introduction . . . 526
16.2 Translation . . . 527
16.3 Centroidal Rotation . . . 535
16.4 Systems of Rigid Bodies . . . 537
16.5 Plane Motion . . . 543

16.6 Dynamic Equilibrium in Plane Motion 544
16.7 Plane Motion Consisting of a Translation and of an Unrelated Centroidal Rotation 546
16.8 Noncentroidal Rotation 551
16.9 Rolling Motion 559
16.10 Other Types of Plane Motion 566
16.11 Rotating Shafts 571
*16.12 Rotation of a Three-dimensional Body about a Fixed Axis 573

Chapter 17 Kinetics of Rigid Bodies: Work and Energy . . . 582

17.1 Principle of Work and Energy for a Rigid Body 582
17.2 Work of Forces Acting on a Rigid Body 583
17.3 Kinetic Energy in Translation 584
17.4 Kinetic Energy in Rotation 585
17.5 Systems of Rigid Bodies 585
17.6 Kinetic Energy in Plane Motion 591
17.7 Conservation of Energy 592
17.8 Power 593

Chapter 18 Kinetics of Rigid Bodies: Impulse and Momentum . . 602

18.1 Introduction 602
18.2 Angular Impulse and Angular Momentum 603
18.3 Principle of Impulse and Momentum for a Rigid Body 605
18.4 Translation 605
18.5 Centroidal Rotation 605
18.6 Systems of Rigid Bodies 606
18.7 Plane Motion 611
18.8 Conservation of Angular Momentum 617
18.9 Eccentric Impact 618
*18.10 Gyroscopes. 628

Chapter 19 Mechanical Vibrations 635

19.1 Introduction 635

VIBRATIONS WITHOUT DAMPING

19.2 Free Vibrations of Particles. Simple Harmonic Motion 636
19.3 Simple Pendulum (Approximate Solution). 640
*19.4 Simple Pendulum (Exact Solution). 641
19.5 Free Vibrations of Rigid Bodies 646
19.6 Application of the Principle of Conservation of Energy 655
19.7 Forced Vibrations. 660

DAMPED VIBRATIONS

*19.8 Damped Free Vibrations. 667
*19.9 Damped Forced Vibrations 669

Index xvii

Answers to Even-numbered Problems . . . . . *(following Index)*