Contents

Preface ix

List of Symbols xiii

1
INTRODUCTION 1

1.1 What Is Mechanics? 1
1.2 Fundamental Concepts and Principles 2
1.3 Systems of Units 5
1.4 Conversion from One System of Units to Another 11
1.5 Method of Problem Solution 14
1.6 Numerical Accuracy 15

2
STATICS OF PARTICLES 16

FORCES IN A PLANE 16

2.1 Force on a Particle. Resultant of Two Forces 16
2.2 Vectors 17
2.3 Addition of Vectors 18
2.4 Resultant of Several Concurrent Forces 21
2.5 Resolution of a Force into Components 21
2.6 Rectangular Components of a Force. Unit Vectors 27
2.7 Addition of Forces by Summing x and y Components 30
2.8 Equilibrium of a Particle 35
2.9 Newton's First Law of Motion 36
2.10 Problems Involving the Equilibrium of a Particle. Free-Body Diagram 36

FORCES IN SPACE 43

2.11 Rectangular Components of a Force in Space 43
2.12 Force Defined by Its Magnitude and Two Points on Its Line of Action 47
2.13 Addition of Concurrent Forces in Space 48
2.14 Equilibrium of a Particle in Space 52

3
RIGID BODIES: EQUIVALENT SYSTEMS OF FORCES 59

3.1 Rigid Bodies. External and Internal Forces 59
3.2 Principle of Transmissibility. Equivalent Forces 61
3.3 Vector Product of Two Vectors 63
3.4 Vector Products Expressed in Terms of Rectangular Components 65
3.5 Moment of a Force about a Point 67
3.6 Varignon's Theorem 69
3.7 Rectangular Components of the Moment of a Force 70
3.8 Scalar Product of Two Vectors 77
3.9 Mixed Triple Product of Three Vectors 80
3.10 Moment of a Force about a Given Axis 81
3.11 Moment of a Couple 88
3.12 Equivalent Couples 89
3.13 Addition of Couples 91
3.14 Couples May Be Represented by Vectors 92
3.15 Resolution of a Given Force into a Force at *O* and a Couple 93
3.16 Reduction of a System of Forces to One Force and One Couple 102
3.17 Equivalent Systems of Forces 103
3.18 Equipollent Systems of Vectors 104
3.19 Further Reduction of a System of Forces 104

4
EQUILIBRIUM OF RIGID BODIES 122

4.1 Rigid Body in Equilibrium 122
4.2 Free-Body Diagram 123

EQUILIBRIUM IN TWO DIMENSIONS 124

4.3 Reactions at Supports and Connections for a Two-dimensional Structure 124
4.4 Equilibrium of a Rigid Body in Two Dimensions 126
4.5 Statically Indeterminate Reactions. Partial Constraints 128
4.6 Equilibrium of a Two-Force Body 143
4.7 Equilibrium of a Three-Force Body 144

EQUILIBRIUM IN THREE DIMENSIONS 150

4.8 Reactions at Supports and Connections for a Three-dimensional Structure 150
4.9 Equilibrium of a Rigid Body in Three Dimensions 152

5
DISTRIBUTED FORCES: CENTROIDS AND CENTERS OF GRAVITY 166

AREAS AND LINES 166

5.1 Center of Gravity of a Two-dimensional Body 166
5.2 Centroids of Areas and Lines 168
5.3 Composite Plates and Wires 172
5.4 Determination of Centroids by Integration 181
5.5 Theorems of Pappus-Guldinus 182
***5.6** Distributed Loads on Beams 191
***5.7** Forces on Submerged Surfaces 192

VOLUMES 199

5.8 Center of Gravity of a Three-dimensional Body. Centroid of a Volume 199
5.9 Composite Bodies 201
5.10 Determination of Centroids of Volumes by Integration 203

6
ANALYSIS OF STRUCTURES 213

6.1 Internal Forces. Newton's Third Law 213

TRUSSES 214

6.2 Definition of a Truss 214
6.3 Simple Trusses 216
6.4 Analysis of Trusses by the Method of Joints 216
***6.5** Joints under Special Loading Conditions 220
***6.6** Space Trusses 222
6.7 Analysis of Trusses by the Method of Sections 228
***6.8** Trusses Made of Several Simple Trusses 230

FRAMES AND MACHINES 238

6.9 Structures Containing Multiforce Members 238
6.10 Analysis of a Frame 238
6.11 Frames Which Cease to Be Rigid When Detached from Their Supports 240
6.12 Machines 253

7
FORCES IN BEAMS AND CABLES 266

***7.1** Introduction. Internal Forces in Members 266

BEAMS 270

*7.2 Various Types of Loading and Support 270
*7.3 Shear and Bending Moment in a Beam 272
*7.4 Shear and Bending-Moment Diagrams 274
*7.5 Relations between Load, Shear, and Bending Moment 279

CABLES 288

*7.6 Cables with Concentrated Loads 288
*7.7 Cables with Distributed Loads 289
*7.8 Parabolic Cable 290
*7.9 Catenary 297

8
FRICTION 304

8.1 Introduction 304
8.2 The Laws of Dry Friction. Coefficients of Friction 305
8.3 Angles of Friction 307
8.4 Problems Involving Dry Friction 308
8.5 Wedges 321
8.6 Square-threaded Screws 322
*8.7 Journal Bearings. Axle Friction 330
*8.8 Thrust Bearings. Disk Friction 332
*8.9 Wheel Friction. Rolling Resistance 333
8.10 Belt Friction 339

9
DISTRIBUTED FORCES:
MOMENTS OF INERTIA 350

MOMENTS OF INERTIA OF AREAS 350

9.1 Second Moment, or Moment of Inertia, of an Area 350
9.2 Determination of the Moment of Inertia of an Area by Integration 352
9.3 Polar Moment of Inertia 353
9.4 Radius of Gyration of an Area 354
9.5 Parallel-Axis Theorem 359
9.6 Moments of Inertia of Composite Areas 360
*9.7 Product of Inertia 369
*9.8 Principal Axes and Principal Moments of Inertia 371
*9.9 Mohr's Circle for Moments and Products of Inertia 374

MOMENTS OF INERTIA OF MASSES 382

9.10 Moment of Inertia of a Mass 382
9.11 Parallel-Axis Theorem 383
9.12 Moments of Inertia of Thin Plates 385
9.13 Determination of the Moment of Inertia of a Three-dimensional Body by Integration 386
9.14 Moments of Inertia of Composite Bodies 386
***9.15** Moment of Inertia of a Body with Respect to an Arbitrary Axis through *O*. Mass Products of Inertia 396
***9.16** Ellipsoid of Inertia. Principal Axes of Inertia 398

10
METHOD OF VIRTUAL WORK 405

***10.1** Work of a Force 405
***10.2** Principle of Virtual Work 408
***10.3** Application of the Principle of Virtual Work 409
***10.4** Real Machines. Mechanical Efficiency 411
***10.5** Work of a Force during a Finite Displacement 420
***10.6** Potential Energy 423
***10.7** Potential Energy and Equilibrium 424
***10.8** Stability of Equilibrium 426

INDEX **435**

Answers to Even-numbered Problems **439**