### CONTENTS

#### 1 Stress 3



- Chapter Objectives 3
- 1.1 Introduction 3
- 1.2 Equilibrium of a Deformable Body 4
- 1.3 Stress 22
- **1.4** Average Normal Stress in an Axially Loaded Bar 24
- 1.5 Average Shear Stress 32
- 1.6 Allowable Stress Design 46
- 1.7 Limit State Design 48

#### 2 Strain 67



- Chapter Objectives 67
- 2.1 Deformation 67
- 2.2 Strain 68

## Mechanical Properties of Materials 83



- Chapter Objectives 83
- 3.1 The Tension and Compression Test 83
- 3.2 The Stress-Strain Diagram 85
- 3.3 Stress-Strain Behavior of Ductile and Brittle Materials 89
- 3.4 Hooke's Law 92
- 3.5 Strain Energy 94 DeldO retgard
- 3.6 Poisson's Ratio 104 sea not alas a 1.11
- 3.7 The Shear Stress-Strain Diagram 106
- \*3.8 Failure of Materials Due to Creep and Fatigue 109

### Axial Load 121



- Chapter Objectives 121
- 4.1 Saint-Venant's Principle 121
- **4.2** Elastic Deformation of an Axially Loaded Member 124
- 4.3 Principle of Superposition 138
- **4.4** Statically Indeterminate Axially Loaded Member 139
- 4.5 The Force Method of Analysis for Axially Loaded Members 145
- 4.6 Thermal Stress 153
- 4.7 Stress Concentrations 160
- \*4.8 Inelastic Axial Deformation 164
- \*4.9 Residual Stress 166

### Torsion 181



- Chapter Objectives 181
- 5.1 Torsional Deformation of a Circular Shaft 181
- 5.2 The Torsion Formula 184
- **5.3** Power Transmission 192
- 5.4 Angle of Twist 204
- 5.5 Statically Indeterminate Torque-Loaded
  Members 218
- \*5.6 Solid Noncircular Shafts 225
- \*5.7 Thin-Walled Tubes Having Closed Cross Sections 228
- 5.8 Stress Concentration 238 Want 18
- \*5.9 Inelastic Torsion 241
- \*5.10 Residual Stress 243 PapalbsoJ

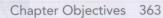
#### 6 Bending 259



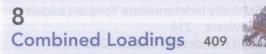


- 6.1 Shear and Moment Diagrams 259
- **6.2** Graphical Method for Constructing Shear and Moment Diagrams 266
- 6.3 Bending Deformation of a Straight Member 285
- **6.4** The Flexure Formula 289
- 6.5 Unsymmetric Bending 306
- \*6.6 Composite Beams 316
- \*6.7 Reinforced Concrete Beams 319
- \*6.8 Curved Beams 323
- 6.9 Stress Concentrations 330
- \*6.10 Inelastic Bending 339

#### 7 Transverse Shear 363



- 7.1 Shear in Straight Members 363
- 7.2 The Shear Formula 365
- 7.3 Shear Flow in Built-Up Members 382
- 7.4 Shear Flow in Thin-Walled Members 391
- \*7.5 Shear Center for Open Thin-Walled Members 396





- Chapter Objectives 409
- 8.1 Thin-Walled Pressure Vessels 409
- 8.2 State of Stress Caused by Combined Loadings 416 Stress Caused Stress Combined Carlotte Stress Caused Stress Ca

#### 9 Stress Transformation 441



Chapter Objectives 441

- 9.1 Plane-Stress Transformation 441
- 9.2 General Equations of Plane-Stress Transformation 446
- 9.3 Principal Stresses and Maximum In-Plane Shear Stress 449
- 9.4 Mohr's Circle—Plane Stress 465
- 9.5 Absolute Maximum Shear Stress 477

#### 10 Strain Transformation 489



Chapter Objectives 489

- 10.1 Plane Strain 489
- 10.2 General Equations of Plane-Strain Transformation 490
- \*10.3 Mohr's Circle—Plane Strain 498
- \*10.4 Absolute Maximum Shear Strain 506
- 10.5 Strain Rosettes 508
- 10.6 Material-Property Relationships 512
- \*10.7 Theories of Failure 524

## 11 Design of Beams and Shafts 541



Chapter Objectives 541

- 11.1 Basis for Beam Design 541
- 11.2 Prismatic Beam Design 544
- \*11.3 Fully Stressed Beams 558
- \*11.4 Shaft Design 562

# 12 Deflection of Beams and Shafts 573



	Cha	s 573	
12.1	The	Elastic Curve	573
	01	1 - 1	

12.2 Slope and Displacement by Integration 577

**\*12.3** Discontinuity Functions 597

\*12.4 Slope and Displacement by the Moment-Area Method 608

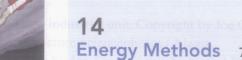
12.5 Method of Superposition 623

**12.6** Statically Indeterminate Beams and Shafts 631

**12.7** Statically Indeterminate Beams and Shafts—Method of Integration 632

\*12.8 Statically Indeterminate Beams and Shafts—Moment-Area Method 637

12.9 Statically Indeterminate Beams and Shafts—Method of Superposition 643





Cha		OL		710
Cha	oter	Ob	ectives	719

14.1 External Work and Strain Energy 719

14.2 Elastic Strain Energy for Various Types of Loading 724

14.3 Conservation of Energy 737

14.4 Impact Loading 744

\*14.5 Principle of Virtual Work 755

\*14.6 Method of Virtual Forces Applied to Trusses 759

\*14.7 Method of Virtual Forces Applied to Beams 766

\*14.8 Castigliano's Theorem 775

\*14.9 Castigliano's Theorem Applied to Trusses 777

\*14.10 Castigliano's Theorem Applied to Beams 780

## 13 Buckling of Columns 661



Chapter Objectives 661

13.1 Critical Load 661

13.2 Ideal Column with Pin Supports 664

13.3 Columns Having Various Types of Supports 670

\*13.4 The Secant Formula 682

\*13.5 Inelastic Buckling 688

\*13.6 Design of Columns for Concentric Loading 696

\*13.7 Design of Columns for Eccentric Loading 707

#### **Appendix**

A. Geometric Properties of an Area 788

B. Geometric Properties of Structural Shapes 804

C. Slopes and Deflections of Beams 812

Solutions and Answers for Preliminary Problems 814

Fundamental Problems Partial Solutions and Answers 825

Selected Answers 844

Index 866