Second Edition

STATICS AND MECHANICS OF MATERIALS

An Integrated Approach



William F. Riley / Leroy D. Sturges / Don H. Morris

Contents

PREFACE

CHAPTER 1: GENERAL PRINCIPLES

- 1-1 Introduction 1
- 1-2 Fundamental Quantities of Mechanics 2

Newton's Laws 3 Mass and Weight 5

1-3 Units of Measurement 8

The U.S. Customary System of Units 9 The International System of Units 9

1-4 Dimensional Considerations 13

Dimensional Homogeneity 13

- 1-5 Method of Problem Solving 16
- 1-6 Significance of Numerical Results 18

The Accuracy of the Known Physical Data 18
The Accuracy of the Physical Model 19
The Accuracy of the Computations Performed 19

1-7 Summary 23

CHAPTER 2: CONCURRENT FORCE SYSTEMS

- 2-1 Introduction 26
- 2-2 Forces and Their Characteristics 26

Scalar Quantities 27 Vector Quantities 27 Principle of Transmissibility 28 Classification of Forces 28

2-3 Resultant of Two or More Concurrent Forces 29

Addition of Vectors 29
Law of Sines and Law of Cosines 30
Resultant of Two Concurrent Forces 30
Resultant of Three or More Concurrent Forces 31

- 2-4 Resolution of a Force into Components 38
- 2-5 Rectangular Components of a Force 43

Unit Vectors 44

Rectangular Components in Two Dimensions 44

Rectangular Components in Three Dimensions 45

The Scalar (Dot) Product and Rectangular

Components 46

- 2-6 Resultants by Rectangular Components 53
- 2-7 Summary 62

CHAPTER 3: EQUILIBRIUM: CONCURRENT FORCE SYSTEMS

- 3-1 Introduction 65
- 3-2 Free-Body Diagrams 66
- 3-3 Equilibrium of a Particle 68

Two-Dimensional Problems 69
Three-Dimensional Problems 69

3-4 Summary 84

CHAPTER 4: STRESS, STRAIN, AND DEFORMATION: AXIAL LOADING

4.1	Introduction	. QQ
a.,	THE PROPERTY OF	1 00

4-2 Axially Loaded Members-Internal Forces 88

Normal Stress Under Axial Loading 89 Shearing Stress in Connections 90 Bearing Stress 92

4-3 Stresses on an Inclined Plane in an Axially Loaded Member 103

- 4-4 Displacement, Deformation, and Strain 108
- 4-5 Stress-Strain-Temperature Relationships 114
 Stress-Strain Diagrams 114
- 4-6 Thermal Strain 125
- 4-7 Deformation of Axially Loaded Members 127
- 4-8 Statically Indeterminate Axially Loaded
 Members 133
- 4-9 Thermal Effects 140
- 4-10 Design 146
- 4-11 Summary 152

CHAPTER 5: EQUIVALENT FORCE/ MOMENT SYSTEMS

- 5-1 Introduction 158
- 5-2 Moments and Their Characteristics 158

Principle of Moments Varignon's Theorem 159

5-3 Vector Representation of a Moment 164

Moment of a Force About a Point 167

- 5-4 Mement of a Force About a Line (Axis) 175
- 5-5 Couples 182

5-6 Equivalent Force-Couple Systems 187

Coplanar Force Systems 188 Noncoplanar Parallel Force Systems 189 General Force Systems 190

5-7 Center of Gravity and Center of Mass 201

Center of Gravity 201 Center of Mass 201

5-8 Centroids of Volumes, Areas, and Lines 205

Centroids of Volumes 205
Centroids of Areas 205
Centroids of Lines 206
Centroid, Center of Mass, or Center of Gravity by
Integration 206

- 5-9 Centroids of Composite Bodies 214
- 5-10 Distributed Loads on Structural Members 225
- 5-11 Summary 231

CHAPTER 6: EQUILIBRIUM: RIGID AND DEFORMABLE BODIES

- 6-1 Introduction 237
- 6-2 Free-Body Diagrams 238

Idealization of Two-Dimensional Supports and Connections 239 Idealization of Three-Dimensional Supports and Connections 242

6-3 Equilibrium in Two Dimensions 248

Two-Force Members 249
Statically Indeterminate Reactions and Partial
Constraints 251

6-4 Frames and Machines 275

Frames 276 Machines 278

Stress and Deformation: Frames and Machines 279

- 6-5 Statically Indeterminate Problems 290
- 6-6 Plane Trusses 299

Method of Joints 302 Zero-Force Members 303 Method of Sections 305

- 6-7 Equilibrium in Three Dimensions 319
- 6-8 Friction 325

Characteristics of Coulomb Friction 325

- 6-9 Flat Belts and V-Belts 339
- 6-10 Design 346
- 6-11 Summary 350

CHAPTER 7: TORSIONAL LOADING: SHAFTS

- 7-1 Introduction 357
- 7-2 Torsional Shearing Strain 359
- 7-3 Torsional Shearing Stress—The Elastic Torsion
 Formula 361
- 7-4 Torsional Displacements 362
- 7-5 Stresses on Oblique Planes 376
- 7-6 Work of Forces and Couples 381
 Work of a Force 381

Work of a Couple 383

- 7-7 Power Transmission of Torsional Shafts 387
- 7-8 Statically Indeterminate Members 391
- 7-9 Design 400
- 7-10 Summary 406

CHAPTER 8: FLEXURAL LOADING: STRESSES IN BEAMS

- 8-1 Introduction 410
- 8-2 Flexural Strains 413
- 8-3 Flexural Stresses 414
- 8-4 Second Moments of Areas 417

Radius of Gyration 417
Parallel-Axis Theorem for Second Moments of
Area 417

Second Moments of Composite Areas 418

- 8-5 The Elastic Flexure Formula 426
- 8-6 Shear Forces and Bending Moments in Beams 435

Shear Force and Bending Moment: An Equilibrium Approach 436

8-7 Load, Shear Force, and Bending Moment

Relationships 446

Shear Force and Bending Moment Diagrams 449

8-8 Shearing Stresses in Beams 461

8-9 Design 475

8-10 Summary 481

CHAPTER 9: FLEXURAL LOADING: BEAM DEFLECTIONS

- 9-1 Introduction 487
- 9-2 The Differential Equation of the Elastic Curve 487
- 9-3 Deflections by Integration 489
- 9-4 Deflections by Integration of Shear-Force or Load
 Equations 502
- 9-5 Singularity Functions 506
- 9-6 Deflections by Superposition 517
- 9-7 Statically Indeterminate Beams: The Integration Method
 525
- 9-8 Statically Indeterminate Beams: The Superposition
 Method 534
- 9-9 Design 540
- 9-10 Summary 547

CHAPTER 10: COMBINED STATIC LOADING

- 10-1 Introduction 551
- 10-2 Stress at a General Point in an Arbitrarily Loaded

 Member 551
- 10-3 Two-Dimensional or Plane Stress 554
- 10-4 The Stress Transformation Equations for Plane Stress 558
- 10-5 Principal Stresses and Maximum Shearing Stress—Plane Stress 564
- 10-6 Mohr's Circle for Plane Stress 576
- 16-7 Two-Dimensional or Plane Strain 585
- 10-8 The Strain Transformation Equations for Plane Strain 587
- 10-9 Principal Strains and Maximum Shearing Strain 592
- 10-10 Mohr's Circle for Plane Strain 594

10-11 Generalized Hooke's Law 595	Table A-4 American Standard Beams (SI Units) 691	
10-12 Strain Measurement and Rosette Analysis 602	Table A-5 Standard Channels (U.S. Customary Units) 692	
10-13 Thin-Walled Pressure Vessels 609	Table A-6 Standard Channels (SI Units) 693	
10-14 Combined Axial, Torsional, and Flexural Loads 614	Table A-7 Equal Leg Angles (U.S. Customary Units) 694	
10-15 Design: Ductile Materials 628	Table A-8 Equal Leg Angles (SI Units) 695	
Maximum-Normal-Stress Theory 628 Maximum-Shear-Stress Theory 629	Table A-9 Unequal Leg Angles (U.S. Customary Units) 696	
Maximum-Distortion-Energy Theory 630	Table A-10 Unequal Leg Angles (SI Units) 697	
10-16 Design: Brittle Materials 642	Table A-11 Structural Tees (U.S. Customary Units) 698	
Coulomb-Mohr and Maximum-Normal-Stress Theories 642	Table A-12 Structural Tees (SI Units) 699	
10-17 Summary 645	Table A-13 Properties of Standard Steel Pipe (U.S. Customary Units) 700	
CHAPTER 11: COLUMNS	Table A-14 Properties of Standard Steel Pipe (SI Units) 701	
11-1 Introduction 651	Table A-15 Properties of Standard Structural Timber (U.S. Customary Units) 702	
11-2 Buckling of Long Straight Columns 652	Table A-16 Properties of Standard Structural Timber	
11-3 Effects of Different Idealized End Conditions 660	(SI Units) 703	
11-4 Empirical Column Formulas—Centric Loading 665	Table A-17 Properties of Selected Engineering Materials	
11-5 Eccentrically Loaded Columns 672	(U.S. Customary Units) 704	
Allowable Stess Method 673 Interaction Method 673	Table A-18 Properties of Selected Engineering Materials (SI Units) 705	
11-6 Design 678	Table A-19 Beam Deflections and Slopes 706	
11-7 Summary 682		
APPENDIX A: TABLES OF PROPERTIES	ANSWERS TO SELECTED PROBLEMS 707	
Table A-1 Wide-Flange Beams (U.S. Customary Units) 688	INDEX 717	
Table A-2 Wide-Flange Beams (SI Units) 689		
Table A-3 American Standard Beams (U.S. Customary		

Units) 690