

MECHANICS OF MATERIALS

NINTH EDITION

Barry J. Goodno | James M. Gere





Mechanics of Materials

Ninth Edition

Barry J. Goodno

Georgia Institute of Technology

James M. Gere

Professor Emeritus, Stanford University



Australia • Brazil • Japan • Korea • Mexico • Singapore • Spain • United Kingdom • United States

Mechanics of Materials, Ninth Edition

Authors: Barry J. Goodno and
James M. Gere

Product Director, Global Engineering:
Timothy L. Anderson

Senior Content Developer: Mona ZefTel

Associate Media Content Developer:
Ashley Kaupert

Product Assistant: Teresa Versaggi

Marketing Manager: Kristin Stine

Director, Higher Education Production:
Sharon L. Smith

Content Project Manager: D. Jean Buttrum

Production Service: RPK Editorial
Services, Inc.

Copyeditor: Patricia Daly

Proofreader: Shelly Gerger-Knechtl

Indexer: Shelly Gerger-Knechtl

Compositor: SPi Global

Senior Art Director: Michelle Kunkler

Cover and Internal Designer:
Lou Ann Thesing

Cover and Internal Image: MACIEJ
NOSKOWSKI/E+/Getty Images

Intellectual Property

Analyst: Christine Myaskovsky

Project Manager: Sarah Shainwald

Text and Image Permissions Researcher:
Kristiina Paul

Manufacturing Planner: Doug Wilke

© 2018, 2013 Cengage Learning®

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced or distributed in any form or by any means, except as permitted by U.S. copyright law, without the prior written permission of the copyright owner.

For product information and technology assistance, contact us at
Cengage Learning Customer & Sales Support, 1-800-354-9706.

For permission to use material from this text or product,
submit all requests online at www.cengage.com/permissions.

Further permissions questions can be emailed to
permissionrequest@cengage.com.

Library of Congress Control Number: 2016952400

ISBN: 978-1-337-09334-7

Cengage Learning

20 Channel Center Street
Boston, MA 02210
USA

Cengage Learning is a leading provider of customized learning solutions with employees residing in nearly 40 different countries and sales in more than 125 countries around the world. Find your local representative at www.cengage.com.

Cengage Learning products are represented in Canada by Nelson Education Ltd.

To learn more about Cengage Learning Solutions, visit
www.cengage.com/engineering.

Purchase any of our products at your local college store or at our preferred online store www.cengagebrain.com.

Unless otherwise noted, all items © Cengage Learning.

About the Authors ix

Preface xi

MindTap Online Course xviii

Symbols xxi

Greek Alphabet xxiv

1. Tension, Compression, and Shear 1

- 1.1 Introduction to Mechanics of Materials 2
- 1.2 Problem-Solving Approach 2
- 1.3 Statics Review 3
- 1.4 Normal Stress and Strain 22
- 1.5 Mechanical Properties of Materials 31
- 1.6 Elasticity, Plasticity, and Creep 38
- 1.7 Linear Elasticity, Hooke's Law, and Poisson's Ratio 44
- 1.8 Shear Stress and Strain 50
- 1.9 Allowable Stresses and Allowable Loads 63
- 1.10 Design For Axial Loads and Direct Shear 70
- Chapter Summary and Review 74
- Problems 77

2. Axially Loaded Members 119

- 2.1 Introduction 120
- 2.2 Changes in Lengths of Axially Loaded Members 120
- 2.3 Changes in Lengths under Nonuniform Conditions 128
- 2.4 Statically Indeterminate Structures 142
- 2.5 Thermal Effects, Misfits, and Prestrains 155
- 2.6 Stresses on Inclined Sections 174
- 2.7 Strain Energy 186
- *2.8 Impact Loading 197
- *2.9 Repeated Loading and Fatigue 205
- *2.10 Stress Concentrations 207
- *2.11 Nonlinear Behavior 214
- *2.12 Elastoplastic Analysis 218
- Chapter Summary and Review 225
- Problems 227

3. Torsion 273

- 3.1 Introduction 274
- 3.2 Torsional Deformations of a Circular Bar 274
- 3.3 Circular Bars of Linearly Elastic Materials 277
- 3.4 Nonuniform Torsion 290
- 3.5 Stresses and Strains in Pure Shear 302
- 3.6 Relationship Between Moduli of Elasticity E and G 309
- 3.7 Transmission of Power by Circular Shafts 311
- 3.8 Statically Indeterminate Torsional Members 315
- 3.9 Strain Energy in Torsion and Pure Shear 319
- 3.10 Torsion of Noncircular Prismatic Shafts 326
- 3.11 Thin-Walled Tubes 336
- *3.12 Stress Concentrations in Torsion 344
- Chapter Summary and Review 349
- Problems 352

4. Shear Forces and Bending Moments 377

- 4.1 Introduction 378
- 4.2 Types of Beams, Loads, and Reactions 378
- 4.3 Shear Forces and Bending Moments 388
- 4.4 Relationships Among Loads, Shear Forces, and Bending Moments 396
- 4.5 Shear-Force and Bending-Moment Diagrams 400
- Chapter Summary and Review 427
- Problems 429

5. Stresses in Beams (Basic Topics) 445

- 5.1 Introduction 446
- 5.2 Pure Bending and Nonuniform Bending 446
- 5.3 Curvature of a Beam 447

- 5.4 Longitudinal Strains in Beams 449
- 5.5 Normal Stress in Beams (Linearly Elastic Materials) 453
- 5.6 Design of Beams for Bending Stresses 466
- 5.7 Nonprismatic Beams 476
- 5.8 Shear Stresses in Beams of Rectangular Cross Section 480
- 5.9 Shear Stresses in Beams of Circular Cross Section 488
- 5.10 Shear Stresses in the Webs of Beams with Flanges 491
- *5.11 Built-Up Beams and Shear Flow 498
- *5.12 Beams with Axial Loads 502
- *5.13 Stress Concentrations in Bending 509
- Chapter Summary and Review 514
- Problems 518

6. Stresses in Beams (Advanced Topics) 553

- 6.1 Introduction 554
- 6.2 Composite Beams 554
- 6.3 Transformed-Section Method 563
- 6.4 Doubly Symmetric Beams with Inclined Loads 571
- 6.5 Bending of Unsymmetric Beams 578
- 6.6 The Shear-Center Concept 589
- 6.7 Shear Stresses in Beams of Thin-Walled Open Cross Sections 590
- 6.8 Shear Stresses in Wide-Flange Beams 593
- 6.9 Shear Centers of Thin-Walled Open Sections 597
- *6.10 Elastoplastic Bending 605
- Chapter Summary and Review 614
- Problems 616

7. Analysis of Stress and Strain 639

- 7.1 Introduction 640
- 7.2 Plane Stress 640
- 7.3 Principal Stresses and Maximum Shear Stresses 648

- 7.4 Mohr's Circle for Plane Stress 656
- 7.5 Hooke's Law for Plane Stress 669
- 7.6 Triaxial Stress 675
- 7.7 Plane Strain 679
- Chapter Summary and Review 694
- Problems 697

8. Applications of Plane Stress (Pressure Vessels, Beams, and Combined Loadings) 719

- 8.1 Introduction 720
- 8.2 Spherical Pressure Vessels 720
- 8.3 Cylindrical Pressure Vessels 726
- 8.4 Maximum Stresses in Beams 733
- 8.5 Combined Loadings 741
- Chapter Summary and Review 766
- Problems 768

9. Deflections of Beams 787

- 9.1 Introduction 788
- 9.2 Differential Equations of the Deflection Curve 788
- 9.3 Deflections by Integration of the Bending-Moment Equation 793
- 9.4 Deflections by Integration of the Shear-Force and Load Equations 804
- 9.5 Method of Superposition 809
- 9.6 Moment-Area Method 818
- 9.7 Nonprismatic Beams 826
- 9.8 Strain Energy of Bending 831
- *9.9 Castigliano's Theorem 836
- *9.10 Deflections Produced by Impact 848
- *9.11 Temperature Effects 850
- Chapter Summary and Review 854
- Problems 856

10. Statically Indeterminate Beams 883

- 10.1 Introduction 884
- 10.2 Types of Statically Indeterminate Beams 884

10.3	Analysis by the Differential Equations of the Deflection Curve	887	References and Historical Notes	1019
10.4	Method of Superposition	893	APPENDIX A: Systems of Units and Conversion Factors	1029
*10.5	Temperature Effects	907	APPENDIX B: Problem Solving	1043
*10.6	Longitudinal Displacements at the Ends of a Beam	914	APPENDIX C: Mathematical Formulas	1051
	Chapter Summary and Review	917	APPENDIX D: Review of Centroids and Moments of Inertia	1057
	Problems	919	APPENDIX E: Properties of Plane Areas	1083
11. Columns	933		APPENDIX F: Properties of Structural-Steel Shapes	1089
11.1	Introduction	934	APPENDIX G: Properties of Structural Lumber	1101
11.2	Buckling and Stability	934	APPENDIX H: Deflections and Slopes of Beams	1103
11.3	Columns with Pinned Ends	942	APPENDIX I: Properties of Materials	1109
11.4	Columns with Other Support Conditions	951	Answers to Problems	1115
11.5	Columns with Eccentric Axial Loads	960	Index	1153
11.6	The Secant Formula for Columns	965		
11.7	Elastic and Inelastic Column Behavior	970		
11.8	Inelastic Buckling	972		
11.9	Design Formulas for Columns	977		
	Chapter Summary and Review	993		
	Problems	996		

*A star attached to a section number indicates a specialized and/or advanced topic.


MECHANICS OF MATERIALS

NINTH EDITION

Barry J. Goodno | James M. Gere

CENGAGE^{brain}.com

To register or access your online learning solution or purchase materials
for your course, visit www.cengagebrain.com.

 CENGAGE
Learning®

ISBN-13: 978-1-337-09334-7

ISBN-10: 1-337-09334-3



9 781337 093347