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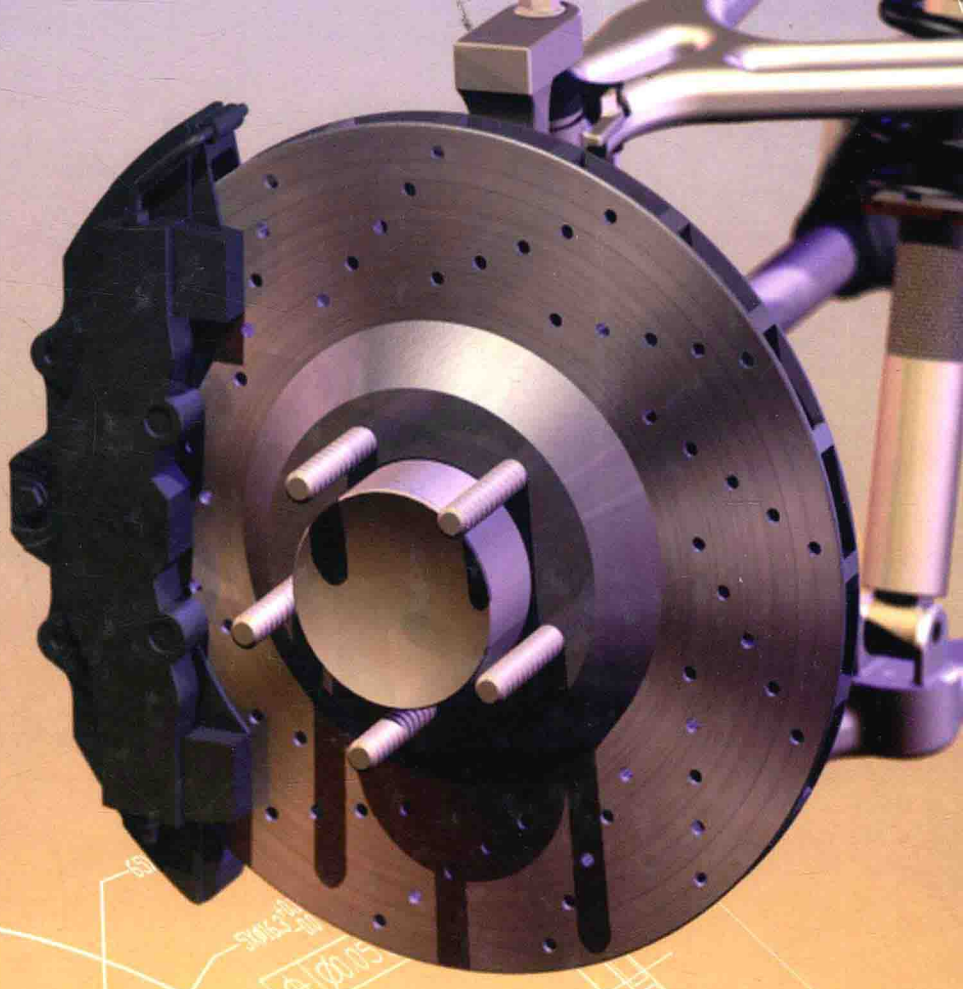

Tenth Edition

Shigley's

Mechanical Engineering Design

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Mc Graw Hill Education

SHIGLEY'S MECHANICAL ENGINEERING DESIGN, TENTH EDITION

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Dedication

To my wife, Joanne, my family, and my late brother, Bill, who advised me to enter the field of mechanical engineering. In many respects, Bill had considerable insight, skill, and inventiveness.

Richard G. Budynas

To my wife, Kim, for her unwavering support.

J. Keith Nisbett

Dedication to Joseph Edward Shigley

Joseph Edward Shigley (1909–1994) is undoubtedly one of the most well-known and respected contributors in machine design education. He authored or coauthored eight books, including *Theory of Machines and Mechanisms* (with John J. Uicker, Jr.), and *Applied Mechanics of Materials*. He was coeditor-in-chief of the well-known *Standard Handbook of Machine Design*. He began *Machine Design* as sole author in 1956, and it evolved into *Mechanical Engineering Design*, setting the model for such textbooks. He contributed to the first five editions of this text, along with coauthors Larry Mitchell and Charles Mischke. Uncounted numbers of students across the world got their first taste of machine design with Shigley's textbook, which has literally become a classic. Nearly every mechanical engineer for the past half century has referenced terminology, equations, or procedures as being from "Shigley." McGraw-Hill is honored to have worked with Professor Shigley for more than 40 years, and as a tribute to his lasting contribution to this textbook, its title officially reflects what many have already come to call it—*Shigley's Mechanical Engineering Design*.

Having received a bachelor's degree in Electrical and Mechanical Engineering from Purdue University and a master of science in Engineering Mechanics from the University of Michigan, Professor Shigley pursued an academic career at Clemson College from 1936 through 1954. This led to his position as professor and head of Mechanical Design and Drawing at Clemson College. He joined the faculty of the Department of Mechanical Engineering of the University of Michigan in 1956, where he remained for 22 years until his retirement in 1978.

Professor Shigley was granted the rank of Fellow of the American Society of Mechanical Engineers in 1968. He received the ASME Mechanisms Committee Award in 1974, the Worcester Reed Warner Medal for outstanding contribution to the permanent literature of engineering in 1977, and the ASME Machine Design Award in 1985.

Joseph Edward Shigley indeed made a difference. His legacy shall continue.

About the Authors

Richard G. Budynas is Professor Emeritus of the Kate Gleason College of Engineering at Rochester Institute of Technology. He has more than 50 years experience in teaching and practicing mechanical engineering design. He is the author of a McGraw-Hill textbook, *Advanced Strength and Applied Stress Analysis,* Second Edition; and coauthor of a McGraw-Hill reference book, *Roark's Formulas for Stress and Strain,* Eighth Edition. He was awarded the BME of Union College, MSME of the University of Rochester, and the PhD of the University of Massachusetts. He is a licensed Professional Engineer in the state of New York.

J. Keith Nisbett is an Associate Professor and Associate Chair of Mechanical Engineering at the Missouri University of Science and Technology. He has more than 30 years of experience with using and teaching from this classic textbook. As demonstrated by a steady stream of teaching awards, including the Governor's Award for Teaching Excellence, he is devoted to finding ways of communicating concepts to the students. He was awarded the BS, MS, and PhD of the University of Texas at Arlington.

to learn in an independent study format. The problems at the end of the chapter are more like quiz questions, and are focused on checking comprehension of the most fundamental concepts. Instructors are encouraged to consider using this chapter as a reading assignment, coupled with even a minimal lecture or online discussion. Of course, there is ample material for expanded presentation and discussion as well.

- Chapter 1, *Introduction to Mechanical Engineering Design,* has been expanded to provide more insight into design practices. Further discussion of the development of the *design factor* is presented, as well as the statistical relationships between *reliability* and the *probability of failure,* and reliability and the design factor. Statistical considerations are provided here rather than in a chapter at the end of the text as in past editions. The section on Dimensions and Tolerances has been expanded to emphasize the designer's role in specifying dimensions and tolerances as a critical part of machine design.
- The chapter of the previous edition, *Statistical Considerations,* has been eliminated. However, the material of that chapter pertinent to this edition has been integrated within the sections that utilize statistics. The stand-alone section on stochastic methods in Chap. 6, *Fatigue Failure Resulting from Variable Loading,* has also been eliminated. This is based on user input and the authors' convictions that the excessive amount of development and data provided in that section was far too involved for the simple class of problems that could be solved. For instructors who still want access to this material, it is available on McGraw-Hill's Online Learning Center at www.mhhe.com/shigley.
- In Chap. 11, *Rolling-Contact Bearings,* the Weibull probability distribution is defined and related to bearing life.
- In conjunction with the Connect Engineering resource, the end-of-chapter problems have been freshly examined to ensure they are clearly stated with less room for vague interpretations. Approximately 50 percent of the problems are targeted for Connect implementation. With the problem parameterization available in this Web-based platform, students can be assigned basic problems with minimal duplication from student to student and semester to semester. For a good balance, this edition maintains many end-of-chapter problems that are open-ended and suitable for exploration and design.

Connect Engineering

The tenth edition continues to feature McGraw-Hill Connect Engineering, a Web-based assignment and assessment platform that allows instructors to deliver assignments, quizzes, and tests easily online. Students can practice important skills at their own pace and on their own schedule.

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Additional media offerings available at www.mhhe.com/shigley include:

Student Supplements

- *Fundamentals of Engineering (FE) exam questions for machine design.* Interactive problems and solutions serve as effective, self-testing problems as well as excellent preparation for the FE exam.

$\mathscr{L}$	Life in hours
l	Length
M	Fundamental dimension mass, moment
$\mathbf{M}$	Moment vector
m	Mass, slope, strain-strengthening exponent
N	Normal force, number, rotational speed, number of cycles
n	Load factor, rotational speed, factor of safety
n_d	Design factor
P	Force, pressure, diametral pitch
PDF	Probability density function
p	Pitch, pressure, probability
Q	First moment of area, imaginary force, volume
q	Distributed load, notch sensitivity
R	Radius, reaction force, reliability, Rockwell hardness, stress ratio, reduction in area
$\mathbf{R}$	Vector reaction force
r	Radius
$\mathbf{r}$	Distance vector
S	Sommerfeld number, strength
s	Distance, sample standard deviation, stress
T	Temperature, tolerance, torque, fundamental dimension time
$\mathbf{T}$	Torque vector
t	Distance, time, tolerance
U	Strain energy
u	Strain energy per unit volume
V	Linear velocity, shear force
v	Linear velocity
W	Cold-work factor, load, weight
w	Distance, gap, load intensity
X	Coordinate, truncated number
x	Coordinate, true value of a number, Weibull parameter
Y	Coordinate
y	Coordinate, deflection
Z	Coordinate, section modulus, viscosity
z	Coordinate, dimensionless transform variable for normal distributions
α	Coefficient, coefficient of linear thermal expansion, end-condition for springs, thread angle
β	Bearing angle, coefficient
Δ	Change, deflection
δ	Deviation, elongation
ϵ	Eccentricity ratio, engineering (normal) strain
ε	True or logarithmic normal strain
Γ	Gamma function, pitch angle
γ	Pitch angle, shear strain, specific weight
λ	Slenderness ratio for springs
μ	Absolute viscosity, population mean
ν	Poisson ratio
ω	Angular velocity, circular frequency
ϕ	Angle, wave length

ψ	Slope integral
ρ	Radius of curvature, mass density
σ	Normal stress
σ'	Von Mises stress
$\hat{\sigma}$	Standard deviation
τ	Shear stress
θ	Angle, Weibull characteristic parameter
¢	Cost per unit weight
$	Cost

Brief Contents

Contents