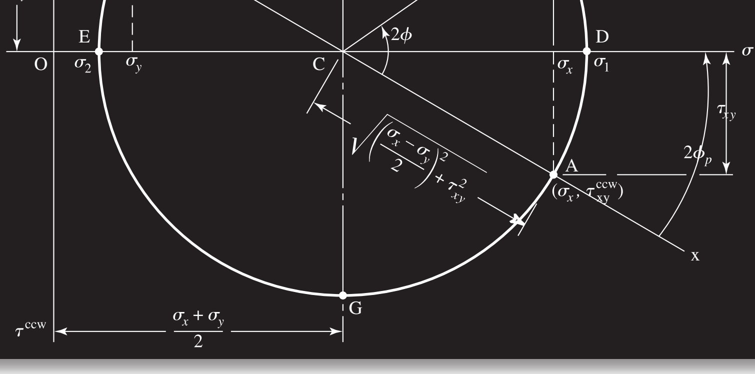

Shigley's Mechanical Engineering Design

2024 Release

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Missouri University of Science and Technology

Mc Graw Hill

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Dedication

To Richard Budynas, in appreciation of his mentorship, his attention to detail, and his contributions to the engineering profession.

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 Author

J. Keith Nisbett is an Associate Professor of Mechanical Engineering at the Missouri University of Science and Technology. He has more than 40 years of experience with using and teaching from this classic textbook. He was awarded the BS, MS, and PhD of the University of Texas at Arlington.

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Preface

Objectives

This text is intended for students beginning the study of mechanical engineering design. The focus is on blending fundamental development of concepts with practical specification of components. Students of this text should find that it inherently directs them into familiarity with both the basis for decisions and the standards of industrial components. For this reason, as students transition to practicing engineers, they will find that this text is indispensable as a reference text. The objectives of the text are to:

- Cover the basics of machine design, including the design process, engineering mechanics and materials, failure prevention under static and variable loading, and characteristics of the principal types of mechanical elements.
- Offer a practical approach to the subject through a wide range of real-world applications and examples.
- Encourage readers to link design and analysis.
- Encourage readers to link fundamental concepts with practical component specification.

New to This Release

Enhancements and modifications to this release are described in the following summaries:

- Chapter 3, *Load and Stress Analysis*. This foundational topic is often assumed to be understood from a previous course in Mechanics of Materials. However, students benefit greatly from a review that focuses their attention on the conceptual basis behind the math, and on being able to home in on the most needed aspects for machine design. This core topic is given a fresh presentation. The goal is to properly identify critical stress elements. This requires clarity in using free-body diagrams, identifying internal stresses, visualizing a stress element, and determining extreme stresses from the stress element.
- Chapter 4, *Deflection and Stiffness*. The coverage of singularity functions in Section 4–6 has been expanded to cover the method sufficiently without assuming prior exposure. The coverage from Section 3–3 has been merged into an expanded consolidated coverage in Section 4–6. The Euler–Bernoulli beam theory is more thoroughly explained in Section 4–3.
- Chapter 14, *Spur and Helical Gears*. The AGMA safety factors are now treated as design factors (as defined by AGMA) to account for unquantifiable aspects of the application. New factors of safety are defined to represent the typical comparison of stress to allowable stress. Also, new factors of safety are introduced to allow linear comparison of load-based failure.

- Chapter 10, *Mechanical Springs*. For fatigue loading of helical compression springs, the Zimmerli experiments and the recommendations based on them are better explained.
- Chapter 1, *Introduction to Mechanical Engineering Design*. This chapter has been generally edited for cleaner presentation. Notable changes are found in Sections 1–9, 1–10, and 1–11 with regard to stress, strength, uncertainty, and factor of safety.

The following sections received notable improvements in presentation:

Section 1–5 The Design Engineer's Professional Responsibilities
Section 1–9 Stress and Strength
Section 1–10 Uncertainty
Section 1–11 Design Factor and Factor of Safety
Section 3–1 Equilibrium and Free-Body Diagrams
Section 3–2 Shear Force and Bending Moments in Beams
Section 3–4 Stress
Section 3–5 Cartesian Stress Components
Section 3–6 Mohr's Circle for Plane Stress
Section 3–7 General Three-Dimensional Stress
Section 3–9 Uniformly Distributed Stresses (direct shear)
Section 3–11 Shear Stresses for Beams in Bending (new Example 3–9)
Section 3–12 Torsion (Noncircular Cross Sections; Power Relations)
Section 3–14 Stresses in Pressurized Cylinders
Section 3–15 Stresses in Rotating Rings
Section 4–3 Deflection Due to Bending
Section 4–6 Beam Deflections by Singularity Functions
Section 5–3 Failure Theories
Section 6–3 Crack Nucleation and Propagation (additional failure examples)
Section 8–2 The Mechanics of Power Screws
Section 10–4 Compression Springs (presetting)
Section 10–9 Fatigue Loading of Helical Compression Springs
Section 13–7 Interference (new interference tables)
Section 14–8 Overload Factor K_o
Section 14–17 Safety Factors S_F and S_H
Section 14–18 Analysis (Factors of safety; updated example problems; updated summary pages)
Section 14–19 Design of a Gear Mesh (updated example problem)

In keeping with the well-recognized accuracy and consistency within this text, minor improvements and corrections are made throughout with each release. Many of these are in response to the diligent feedback from the community of users.

Instructor Supplements

Additional media offerings available in the Instructor Resources include:

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- Including more diverse voices in the development and review of our content.
- Strengthening art guidelines to improve accessibility by ensuring meaningful text and images are distinguishable and perceivable by users with limited color vision and moderately low vision.

Acknowledgments

The authors would like to acknowledge those who have contributed to this text for over 50 years. Input from instructors, students, and engineers is instrumental in keeping this text current and clean from errors.

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List of Symbols

This is a list of common symbols used in machine design and in this book. Specialized use in a subject-matter area often attracts fore and post subscripts and superscripts. To make the table brief enough to be useful, the symbol kernels are listed. See Table 14–1 for spur and helical gearing symbols, and Table 15–1 for bevel-gear symbols.

A	Area, coefficient
a	Distance
B	Coefficient, bearing length
Bhn	Brinell hardness
b	Distance, fatigue strength exponent, Weibull shape parameter, width
C	Basic load rating, bolted-joint constant, center distance, coefficient of variation, column end condition, correction factor, specific heat capacity, spring index, radial clearance
c	Distance, fatigue ductility exponent, radial clearance
COV	Coefficient of variation
D	Diameter, helix diameter
d	Diameter, distance
E	Modulus of elasticity, energy, error
e	Distance, eccentricity, efficiency, Naperian logarithmic base
F	Force, fundamental dimension force
f	Coefficient of friction, frequency, function
fom	Figure of merit
G	Torsional modulus of elasticity
g	Acceleration due to gravity, function
H	Heat, power
H_B	Brinell hardness
HRC	Rockwell C-scale hardness
h	Distance, film thickness
$\hbar_{CR}$	Combined overall coefficient of convection and radiation heat transfer
I	Integral, linear impulse, mass moment of inertia, second moment of area
i	Index
$\mathbf{i}$	Unit vector in x-direction
J	Mechanical equivalent of heat, polar second moment of area, geometry factor
$\mathbf{j}$	Unit vector in the y-direction
K	Service factor, stress-concentration factor, stress-augmentation factor, torque coefficient
k	Marin endurance limit modifying factor, spring rate
$\mathbf{k}$	Unit vector in the z-direction
L	Length, life, fundamental dimension length

$\mathscr{L}$	Life in hours
l	Length
M	Fundamental dimension mass, moment
$\mathbf{M}$	Moment vector, mobility 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
ε	Engineering strain
$\tilde{\varepsilon}$	True or logarithmic strain
$\tilde{\varepsilon}_f$	True fracture strain
ε'_f	Fatigue ductility coefficient
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_a	Alternating stress, stress amplitude
σ_{ar}	Completely reversed alternating stress
σ_m	Mean stress
σ_0	Nominal stress, strength coefficient or strain-strengthening coefficient
σ_f'	Fatigue strength coefficient
$\tilde{\sigma}$	True stress
$\tilde{\sigma}_f$	True fracture strength
σ'	Von Mises stress
$\hat{\sigma}$	Standard deviation
τ	Shear stress
θ	Angle, Weibull characteristic parameter
¢	Cost per unit weight
$	Cost

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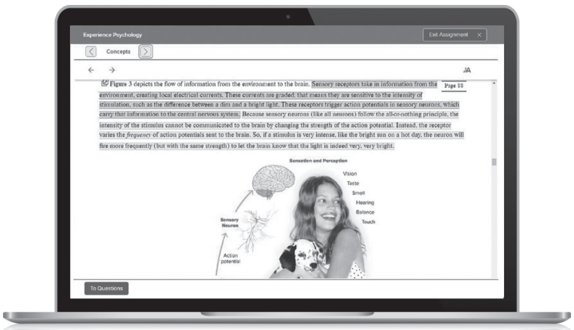

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