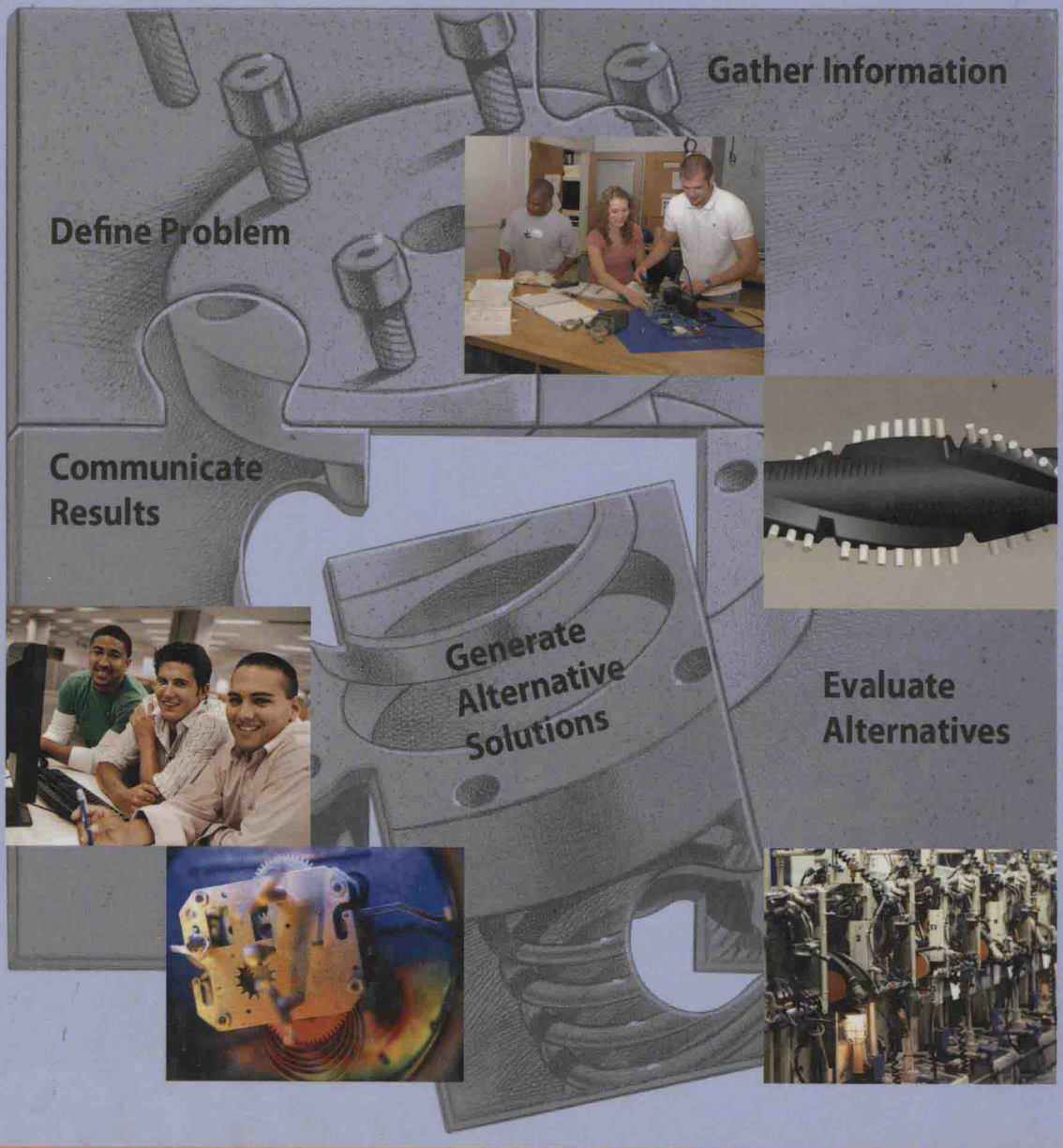
Engineering Design

Fourth Edition



George E. Dieter • Linda C. Schmidt

Engineering Design provides a realistic understanding of the engineering design process. The book presents in detail (Chapters 1 through 9) an eight-step process that gives prescriptive guidance to the student from problem definition through detail design. Chapters 10 through 16 present more specific treatment of specialty topics (design for X). The text is intended to be a used in either a junior or senior engineering course with an integrated hands-on design project.

Outstanding Features Include:

- Uniform terminology is used throughout.
- Expanded discussion of design tools like benchmarking, QFD, creativity methods, functional decomposition and synthesis, and the decision process and decision tools.
- Different approaches to the steps of design are introduced in Chapters 6 and 7, so that students appreciate the range of practice and scholarship on design.
- Separate chapters that present in-depth treatment of design topics such as materials selection, design for manufacturing, robust design, reliability, and cost evaluation.
- Cohesive structure for the design process that students can use with a variety of design methods and software packages.

Many references to the literature have been included as well as suggestions for useful design software and references to web sites.

Changes to the Fourth Edition:

- New topics added or expanded such as: work breakdown structure, AHP, tolerances (including GD&T), human factors design, design against wear, the role of standardization in DFMA, mistake-proofing, and six sigma quality. As a new feature, each chapter ends with a list of new concepts and terms. Expanded examples add realism to key topics.
- Two additional chapters are available to the student at the text website. These are:

  Chapter 17 – Legal and Ethical Issues in Engineering Design
  Chapter 18 – Economic Decision Making

Further resources that support the text are also available on the website at:
www.mhhe.com/dieter

ISBN 978-0-07-283703-2
MHID 0-07-283703-9

EAN 9 780072 837032 90000

www.mhhe.com

The McGraw-Hill Companies

McGraw-Hill Higher Education

DIETER
SCHMIDT

ENGINEERING DESIGN

Fourth
Edition

McGraw
Hill

ENGINEERING DESIGN

FOURTH EDITION

George E. Dieter
University of Maryland

Linda C. Schmidt
University of Maryland

McGraw-Hill Higher Education

Boston Burr Ridge, IL Dubuque, IA New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto

McGraw-Hill Higher Education

ENGINEERING DESIGN, FOURTH EDITION

1 2 3 4 5 6 7 8 9 0 DOC/DOC 0 9 8

ISBN 978–0–07–283703–2
MHID 0–07–283703–9

Global Publisher: *Raghothaman Srinivasan*
Senior Sponsoring Editor: *Bill Stenquist*
Director of Development: *Kristine Tibbetts*
Developmental Editor: *Lorraine K. Buczek*
Senior Project Manager: *Kay J. Brimeyer*
Senior Production Supervisor: *Laura Fuller*
Associate Design Coordinator: *Brenda A. Rolwes*
Cover Designer: *Studio Montage, St. Louis, Missouri*
Cover Illustration: *Paul Turnbaugh*
(USE) Cover Image: *Group of Students: © 2007, Al Santos, Photographer; Vacuum Roller: © Brian C. Grubel; Machinery: © John A. Rizzo/Getty Images; Gears and Machinery: © Nick Koudis/Getty Images; University Students Using Library Computers: BananaStock/ Jupiter Images*
Compositor: *Newgen*
Typeface: *10.5/12 Times Roman*
Printer: *R. R. Donnelley Crawfordsville, IN*

Library of Congress Cataloging-in-Publication Data

Dieter, George Ellwood.
Engineering design / George E. Dieter, Linda C. Schmidt. — 4th ed.
p. cm.
Includes bibliographical references and indexes.
ISBN 978-0-07-283703-2 — ISBN 0-07-283703-9 (hard copy : alk. paper)
1. Engineering design. I. Schmidt, Linda C. II. Title.
TA174.D495 2009
620′.0042—dc22

2007049735

www.mhhe.com

ENGINEERING DESIGN

ABOUT THE AUTHORS

GEORGE E. DIETER is Glenn L. Martin Institute Professor of Engineering at the University of Maryland. The author received his B.S. Met.E. degree from Drexel University and his D.Sc. degree from Carnegie Mellon University. After a stint in industry with the DuPont Engineering Research Laboratory, he became head of the Metallurgical Engineering Department at Drexel University, where he later became Dean of Engineering. Professor Dieter later joined the faculty of Carnegie Mellon University as Professor of Engineering and Director of the Processing Research Institute. He moved to the University of Maryland in 1977 as professor of Mechanical Engineering and Dean of Engineering, serving as dean until 1994.

Professor Dieter is a fellow of ASM International, TMS, AAAS, and ASEE. He has received the education award from ASM, TMS, and SME, as well as the Lamme Medal, the highest award of ASEE. He has been chair of the Engineering Deans Council, and president of ASEE. He is a member of the National Academy of Engineering. He also is the author of *Mechanical Metallurgy,* published by McGraw-Hill, now in its third edition.

LINDA C. SCHMIDT is an Associate Professor in the Department of Mechanical Engineering at the University of Maryland. Dr. Schmidt's general research interests and publications are in the areas of mechanical design theory and methodology, design generation systems for use during conceptual design, design rationale capture, and effective student learning on engineering project design teams.

Dr. Schmidt completed her doctorate in Mechanical Engineering at Carnegie Mellon University with research in grammar-based generative design. She holds B.S. and M.S. degrees from Iowa State University for work in Industrial Engineering. Dr. Schmidt is a recipient of the 1998 U.S. National Science Foundation *Faculty Early Career Award* for generative conceptual design. She co-founded RISE, a summer research experience that won the 2003 Exemplary Program Award from the American College Personnel Association's Commission for Academic Support in Higher Education.

Dr. Schmidt is active in engineering design theory research and teaching engineering design to third- and fourth-year undergraduates and graduate students in mechanical engineering. She has coauthored a text on engineering decision-making, two editions of a text on product development, and a team-training curriculum for faculty using engineering student project teams. Dr. Schmidt was the guest editor of the *Journal of Engineering Valuation & Cost Analysis* and has served as an Associate Editor of the ASME *Journal of Mechanical Design.* Dr. Schmidt is a member of ASME, SME, and ASEE.

PREFACE TO FOURTH EDITION

THE FOURTH EDITION of *Engineering Design* represents the reorganization and expansion of the topics and the introduction of a coauthor, Dr. Linda Schmidt of the Mechanical Engineering Department, University of Maryland. As in previous editions, *Engineering Design* is intended to provide a realistic understanding of the engineering design process. It is broader in content than most design texts, but it now contains more prescriptive guidance on how to carry out design. The text is intended to be used in either a junior or senior engineering course with an integrated hands-on design project. The design process material is presented in a sequential format in Chapters 1 through 9. At the University of Maryland we use Chapters 1 through 9 with junior students in a course introducing the design process. Chapters 10 through 17 present more intense treatment of sophisticated design content, including materials selection, design for manufacturing, and quality. The complete text is used in the senior capstone design course that includes a complete design project from selecting a market to creating a working prototype. Students move quickly through the first nine chapters and emphasize chapters 10 through 17 for making embodiment design decisions.

The authors recognize deterrents to learning the design process. Design is a complex process to teach in a short amount of time. Students are aware of a myriad of design texts and tools and become overwhelmed with the breadth of design approaches. One challenge of the design instructor's task is to convey to the student that engineering design is not a mathematical equation to be solved or optimized. Another is to provide students with a cohesive structure for the design process that they can use with a variety of design methods and software packages. Toward that end, we have adopted a uniform terminology throughout and reinforced this with a new section at the end of each chapter on New Terms and Concepts. We have emphasized a cohesive eight-step engineering design process and present all material in the context of how it is applied. Regardless, we are strong in the belief that to learn design you must do design. We have found that Chapter 4, Team Behavior and Tools, is helpful to the students in this regard. Likewise, we hope that the expanded discussion of design tools like benchmarking, QFD, creativity methods, functional decomposition

and synthesis, and the decision process and decision tools will benefit the students who read this book.

Many new topics have been added or expanded. These include: work breakdown structure, tolerances (including GD&T), human factors design, rapid prototyping, design against wear, the role of standardization in DFMA, mistake-proofing, Six Sigma quality, and the make-buy decision. Finally we have introduced different approaches to the steps of design so that students appreciate the range of practice and scholarship on the topic of engineering design.

The authors hope that students will consider this book to be a valuable part of their professional library. In order to enhance its usefulness for that purpose, many references to the literature have been included, as well as suggestions for useful design software and references to websites. Many of the references have been updated, all of the websites from the third edition have been checked for currency, and many new ones have been added. In a book that covers such a wide sweep of material it has not always been possible to go into depth on every topic. Where expansion is appropriate, we have given a reference to at least one authoritative source for further study.

Special thanks go to Amir Baz, Patrick Cunniff, James Dally, Abhijit Dasgupta, S.K. Gupta, Patrick McCloskey, and Guangming Zhang, our colleagues in the Mechanical Engineering Department, University of Maryland, for their willingness to share their knowledge with us. Thanks also go to Greg Moores of Black & Decker, Inc. for his willingness to share his industrial viewpoint on certain topics. We must also thank the following reviewers for their many helpful comments and suggestions: Charles A. Bollfrass, Texas A&M University; Peter Jones, Auburn University; Cesar A. Luongo, Florida State University; Dr. Michelle Nearon, Stony Brook University; John E. Renaud, University of Notre Dame; Robert Sterlacci, Binghamton University; Daniel T. Valentine, Clarkson University; and Savas Yavuzkurt, Penn State University.

George E. Dieter and Linda C. Schmidt
College Park, MD
2007

BRIEF CONTENTS

DETAILED CONTENTS