

PREFACE

I have been a designer all my life. I have designed bicycles, medical equipment, furniture, and sculpture, both static and dynamic. Designing objects has come easy for me. I have been fortunate in having whatever talents are necessary to be a successful designer. However, after a number of years of teaching mechanical design courses, I came to the realization that I didn't know how to teach what I knew so well. I could show students examples of good-quality design and poor-quality design. I could give them case histories of designers in action. I could suggest design ideas. But I could not tell them what to do to solve a design problem. Additionally, I realized from talking with other mechanical design teachers that I was not alone.

This situation reminded me of an experience I had once had on ice skates. As a novice skater I could stand up and go forward, lamely. A friend (a teacher by trade) could easily skate forward and backward as well. He had been skating since he was a young boy, and it was second nature to him. One day while we were skating together, I asked him to teach me how to skate backward. He said it was easy, told me to watch, and skated off backward. But when I tried to do what he did, I immediately fell down. As he helped me up, I asked him to tell me exactly what to do, not just show me. After a moment's thought, he concluded that he couldn't actually describe the feat to me. I still can't skate backward, and I suppose he still can't explain the skills involved in skating backward. The frustration that I felt falling down as my friend skated with ease must have been the same emotion felt by my design students when I failed to tell them exactly what to do to solve a design problem.

This realization led me to study the process of mechanical design, and it eventually led to this book. Part has been original research, part studying U.S. industry, part studying foreign design techniques, and part trying different teaching approaches on design classes. I came to four basic conclusions about mechanical design as a result of these studies:

1. The only way to learn about design is to do design.
2. In engineering design, the designer uses three types of knowledge: knowledge to generate ideas, knowledge to evaluate ideas and make decisions, and knowledge to structure the design process. Idea generation comes from experience and natural ability. Idea evaluation comes partially from experience and partially from formal training, and is the focus of most engineering education. Generative and evaluative knowledge are forms of domain-specific knowledge. Knowledge about the design process and decision making is largely independent of domain-specific knowledge.
3. A design process that results in a quality product can be learned, provided there is enough ability and experience to generate ideas and enough experience and training to evaluate them.

4. A design process should be learned in a dual setting: in an academic environment and, at the same time, in an environment that simulates industrial realities.

I have incorporated these concepts into this book, which is organized so that readers can learn about the design process at the same time they are developing a product. Chaps. 1–3 present background on mechanical design, define the terms that are basic to the study of the design process, and discuss the human element of product design. Chaps. 4–12, the body of the book, present a step-by-step development of a design method that leads the reader from the realization that there is a design problem to a solution ready for manufacture and assembly. This material is presented in a manner independent of the exact problem being solved. The techniques discussed are used in industry, and their names have become buzzwords in mechanical design: quality function deployment, decision-making methods, concurrent engineering, design for assembly, and Taguchi’s method for robust design. These techniques have all been brought together in this book. Although they are presented sequentially as step-by-step methods, the overall process is highly iterative, and the steps are merely a guide to be used when needed.

As mentioned earlier, domain knowledge is somewhat distinct from process knowledge. Because of this independence, a successful product can result from the design process regardless of the knowledge of the designer or the type of design problem. Even students at the freshman level could take a course using this text and learn most of the process. However, to produce any reasonably realistic design, substantial domain knowledge is required, and it is assumed throughout the book that the reader has a background in basic engineering science, material science, manufacturing processes, and engineering economics. Thus, this book is intended for upper-level undergraduate students, graduate students, and professional engineers who have never had a formal course in the mechanical design process.

ADDITIONS TO THE FOURTH EDITION

Knowledge about the design process is increasing rapidly. A goal in writing the fourth edition was to incorporate this knowledge into the unified structure—one of the strong points of the first three editions. Throughout the new edition, topics have been updated and integrated with other best practices in the book. Some specific additions to the new edition include:

1. Improved material to ensure team success.
2. Over twenty blank templates are available for download from the book’s website (www.mhhe.com/ullman4e) to support activities throughout the design process. The text includes many of them filled out for student reference.
3. Improved material on project planning.

4. Improved sections on Design for the Environment and Design for Sustainability.
5. Improved material on making design decisions.
6. A new section on using contradictions to generate ideas.
7. New examples from the industry, with new photos and diagrams to illustrate the examples throughout.

Beyond these, many small changes have been made to keep the book current and useful.

ELECTRONIC TEXTBOOK

CourseSmart is a new way for faculty to find and review eTextbooks. It's also a great option for students who are interested in accessing their course materials digitally and saving money. CourseSmart offers thousands of the most commonly adopted textbooks across hundreds of courses from a wide variety of higher education publishers. It is the only place for faculty to review and compare the full text of a textbook online, providing immediate access without the environmental impact of requesting a print exam copy. At CourseSmart, students can save up to 50% off the cost of a print book, reduce their impact on the environment, and gain access to powerful Web tools for learning including full text search, notes and highlighting, and email tools for sharing notes between classmates. www.CourseSmart.com

ACKNOWLEDGMENTS

I would like to thank these reviewers for their helpful comments:

Patricia Brackin, *Rose-Hulman Institute of Technology*

William Callen, *Georgia Institute of Technology*

Xiaoping Du, *University of Missouri-Rolla*

Ian Grosse, *University of Massachusetts–Amherst*

Karl-Heinrich Grote, *Otto-von-Guericke University, Magdeburg, Germany*

Mica Grujicic, *Clemson University*

John Halloran, *University of Michigan*

Peter Jones, *Auburn University*

Mary Kasarda, *Virginia Technical College*

Jesa Kreiner, *California State University–Fullerton*

Yuyi Lin, *University of Missouri–Columbia*

Ron Lumia, *University of New Mexico*

Spencer Magleby, *Brigham Young University*

Lorin Maletsky, *University of Kansas*

Make McDermott, *Texas A&M University*
Joel Ness, *University of North Dakota*
Charles Pezeshki, *Washington State University*
John Renaud, *University of Notre Dame*
Keith Rouch, *University of Kentucky*
Ali Sadegh, *The City College of The City University of New York*
Shin-Min Song, *Northern Illinois University*
Mark Steiner, *Rensselaer Polytechnic Institute*
Joshua Summers, *Clemson University*
Meenakshi Sundaram, *Tennessee Technical University*
Shih-Hsi Tong, *University of California–Los Angeles*
Kristin Wood, *University of Texas*

Additionally, I would like to thank Bill Stenquist, senior sponsoring editor for mechanical engineering of McGraw-Hill, Robin Reed, developmental editor, Kay Brimeyer, project manager, and Lynn Steines, project editor, for their interest and encouragement in this project. Also, thanks to the following who helped with examples in the book:

Wayne Collier, *UGS*
Jason Faircloth, *Marin Bicycles*
Marci Lackovic, *Autodesk*
Samir Mesihovic, *Volvo Trucks*
Professor Bob Paasch, *Oregon State University*
Matt Popik, *Irwin Tools*
Cary Rogers, *GE Medical*
Professor Tim Simpson, *Penn State University*
Ralf Strauss, *Irwin Tools*
Christopher Voorhees, *Jet Propulsion Laboratory*
Professor Joe Zaworski, *Oregon State University*

Last and most important my thanks to my wife, Adele, for her never questioning confidence that I could finish this project.