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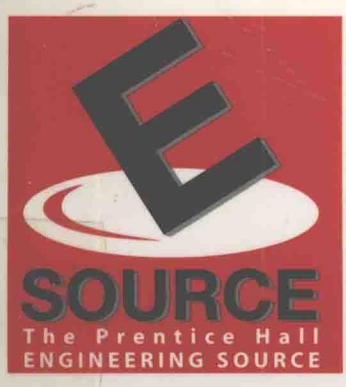

RICHARD M. LUEPTOW • MICHAEL T. SNYDER
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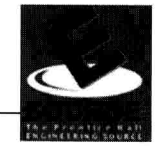

Richard M. Lueptow
Northwestern University

Jim Steger
Michael T. Snyder

Prentice Hall
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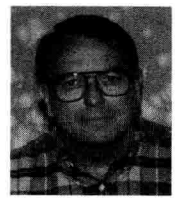
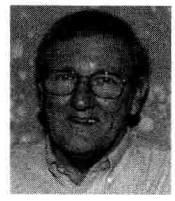
About the Authors

No project could ever come to pass without a group of authors who have the vision and the courage to turn a stack of blank paper into a book. The authors in this series worked diligently to produce their books, provide the building blocks of the series.

Delores M. Etter is a Professor of Electrical and Computer Engineering at the University of Colorado. Dr. Etter was a faculty member at the University of New Mexico and also a Visiting Professor at Stanford University. Dr. Etter was responsible for the Freshman Engineering Program at the University of New Mexico and is active in the Integrated Teaching Laboratory at the University of Colorado. She was elected a Fellow of the Institute of Electrical and Electronics Engineers for her contributions to education and for her technical leadership in digital signal processing. In addition to writing best-selling textbooks for engineering computing, Dr. Etter has also published research in the area of adaptive signal processing.



Sanford Leestma is a Professor of Mathematics and Computer Science at Calvin College, and received his Ph.D. from New Mexico State University. He has been the long-time co-author of successful textbooks on Fortran, Pascal, and data structures in Pascal. His current research interest are in the areas of algorithms and numerical computation.



Larry Nyhoff is a Professor of Mathematics and Computer Science at Calvin College. After doing bachelor's work at Calvin, and Master's work at Michigan, he received a Ph.D. from Michigan State and also did graduate work in computer science at Western Michigan. Dr. Nyhoff has taught at Calvin for the past 34 years—mathematics at first and computer science for the past several years. He has co-authored several computer science textbooks since 1981 including titles on Fortran and C++, as well as a brand new title on Data Structures in C++.

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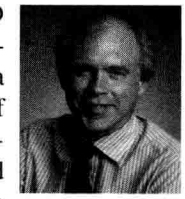
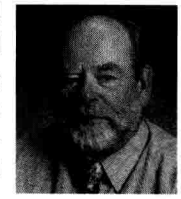
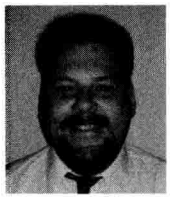


Mark Dix began working with AutoCAD in 1985 as a programmer for CAD Support Associates, Inc. He helped design a system for creating estimates and bills of material directly from AutoCAD drawing databases for use in the automated conveyor industry. This system became the basis for systems still widely in use today. In 1986 he began collaborating with Paul Riley to create AutoCAD training materials, combining Riley's background in industrial design and training with Dix's background in writing, curriculum development, and programming. Dix and Riley have created tutorial and teaching methods for every AutoCAD release since Version 2.5. Mr. Dix has a Master of Education from the University of Massachusetts. He is currently the Director of Dearborn Academy High School in Arlington, Massachusetts.

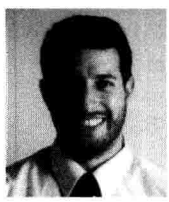


Paul Riley is an author, instructor, and designer specializing in graphics and design for multimedia. He is a founding partner of CAD Support Associates, a contract service and professional training organization for computer-aided design. His 15 years of business experience and 20 years of teaching experience are supported by degrees in education and computer science. Paul has taught AutoCAD at the University of Massachusetts at Lowell and is presently teaching AutoCAD at Mt. Ida College in Newton, Massachusetts. He has developed a program, Computer-aided Design for Professionals that is highly regarded by corporate clients and has been an ongoing success since 1982.

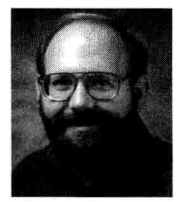


Scott D. James is a staff lecturer at Kettering University (formerly GMI Engineering & Management Institute) in Flint, Michigan. He is currently pursuing a Ph.D. in Systems Engineering with an emphasis on software engineering and computer-integrated manufacturing. Scott decided on writing textbooks after he found a void in the books that were available. "I really wanted a book that showed how to do things in good detail but in a clear and concise way. Many of the books on the market are full of fluff and force you to dig out the really important facts." Scott decided on teaching as a profession after several years in the computer industry. "I thought that it was really important to know what it was like outside of academia. I wanted to provide students with classes that were up to date and provide the information that is really used and needed."
Acknowledgments: Scott would like to acknowledge his family for the time to work on the text and his students and peers at Kettering who offered helpful critiques of the materials that eventually became the book.

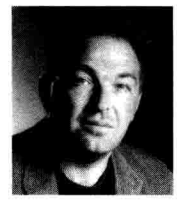
Charles B. Fleddermann is a professor in the Department of Electrical and Computer Engineering at the University of New Mexico in Albuquerque, New Mexico. All of his degrees are in electrical engineering: his Bachelor's degree from the University of Notre Dame, and the Master's and Ph.D. from the University of Illinois at Urbana-Champaign. Prof. Fleddermann developed an engineering ethics course for his department in response to the ABET requirement to incorporate ethics topics into the undergraduate engineering curriculum. *Engineering Ethics* was written as a vehicle for presenting ethical theory, analysis, and problem solving to engineering undergraduates in a concise and readily accessible way.
Acknowledgments: I would like to thank Profs. Charles Harris and Michael Rabins of Texas A & M University whose NSF sponsored workshops on engineering ethics got me started thinking in this field. Special thanks to my wife Liz, who proofread the manuscript for this book, provided many useful suggestions, and who helped me learn how to teach "soft" topics to engineers.



David I. Schwartz is an Assistant Professor in the Computer Science Department at Cornell University and earned his B.S., M.S., and Ph.D. degrees in Civil Engineering from State University of New York at Buffalo. Throughout his graduate studies, Schwartz combined principles of computer science to applications of civil engineering. He became interested in helping students learn how to apply software tools for solving a variety of engineering problems. He teaches his students to learn incrementally and practice frequently to gain the maturity to tackle other subjects. In his spare time, Schwartz plays drums in a variety of bands.
Acknowledgments: I dedicate my books to my family, friends, and students who all helped in so many ways. Many thanks go to the schools of Civil Engineering and Engineering & Applied Science at State University of New York at Buffalo where I originally developed and tested my UNIX and Maple books. I greatly appreciate the opportunity to explore my goals and all the help from everyone at the Computer Science Department at Cornell. Eric Svendsen and everyone at Prentice Hall also deserve my gratitude for helping to make these books a reality. Many thanks, also, to those who submitted interviews and images.



Ron Larsen is an Associate Professor of Chemical Engineering at Montana State University, and received his Ph.D. from the Pennsylvania State University. He was initially attracted to engineering by the challenges the profession offers, but also appreciates that engineering is a serving profession. Some of the greatest challenges he has faced while teaching have involved non-traditional teaching methods, including evening courses for practicing engineers and teaching through an interpreter at the Mongolian National University. These experiences have provided tremendous opportunities to learn new ways to communicate technical material. He tries to incorporate the skills he has learned in non-traditional arenas to improve his lectures, written materials, and learning programs. Dr. Larsen views modern software as one of the new tools that will radically alter the way engineers work, and his book *Introduction to Mathcad* was written to help young engineers prepare to meet the challenges of an ever-changing workplace.
Acknowledgments: To my students at Montana State University who have endured the rough drafts and typos, and who still allow me to experiment with their classes—my sincere thanks.



Peter Schiavone is a professor and student advisor in the Department of Mechanical Engineering at the University of Alberta, Canada. He received his Ph.D. from the University of Strathclyde, U.K. in 1988. He has authored several books in the area of student academic success as well as numerous papers in international scientific research journals. Dr. Schiavone has worked in private

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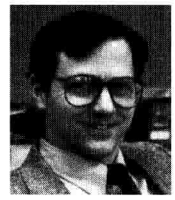
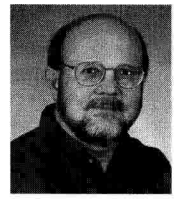
industry in several different areas of engineering including aerospace and systems engineering. He founded the first Mathematics Resource Center at the University of Alberta, a unit designed specifically to teach new students the necessary *survival skills* in mathematics and the physical sciences required for success in first-year engineering. This led to the Students' Union Gold Key Award for outstanding contributions to the university. Dr. Schiavone lectures regularly to freshman engineering students and to new engineering professors on engineering success, in particular about maximizing students' academic performance. He wrote the book *Engineering Success* in order to share the *secrets of success in engineering study*: the most effective, tried and tested methods used by the most successful engineering students.

Acknowledgements: Thanks to Eric Svendsen for his encouragement and support; to Richard Felder for being such an inspiration; to my wife Linda for sharing my dreams and believing in me; and to Francesca and Antonio for putting up with Dad when working on the text.

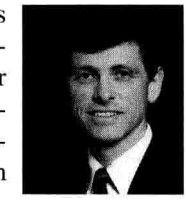


Mark N. Horenstein is a Professor in the Department of Electrical and Computer Engineering at Boston University. He has degrees in Electrical Engineering from M.I.T. and U.C. Berkeley and has been involved in teaching engineering design for the greater part of his academic career. He devised and developed the senior design project class taken by all electrical and computer engineering students at Boston University. In this class, the students work for a virtual engineering company developing products and systems for real-world engineering and social-service clients. Many of the design projects developed in his class have been aimed at assistive technologies for individuals with disabilities.

Acknowledgments: I would like to thank Prof. James Bethune, the architect of the Peak Performance event at Boston University, for his permission to highlight the competition in my text. Several of the ideas relating to brainstorming and teamwork were derived from a workshop on engineering design offered by Prof. Charles Lovas of Southern Methodist University. The principles of estimation were derived in part from a freshman engineering problem posed by Prof. Thomas Kincaid of Boston University.

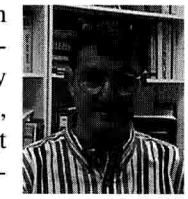


Kirk D. Hagen is a professor at Weber State University in Ogden, Utah. He has taught introductory-level engineering courses and upper-division thermal science courses at WSU since 1993. He received his B.S. degree in physics from Weber State College and his M.S. degree in mechanical engineering from Utah State University, after which he worked as a thermal designer/analyst in the aerospace and electronics industries. After several years of engineering practice, he resumed his formal education, earning his Ph.D. in mechanical engineering at the University of Utah. Hagen is the author of an undergraduate heat transfer text. Having drawn upon his industrial and teaching experience, he strongly believes that engineering students must develop effective analytical problem solving abilities. His book, *Introduction to Engineering Analysis*, was written to help beginning engineering students learn a systematic approach to engineering analysis.



Richard M. Lueptow is the Charles Deering McCormick Professor of Teaching Excellence and Associate Professor of Mechanical Engineering at Northwestern University. He is a native of Wisconsin and received his doctorate from the Massachusetts Institute of Technology in 1986. He teaches design, fluid mechanics, and spectral analysis techniques. "In my design class I saw a need for a self-paced tutorial for my students to learn CAD software quickly and easily. I worked with several students a few years ago to develop just this type of tutorial, which has since evolved into a book. My goal is to introduce students to engineering graphics and CAD, while showing them how much fun it can be." Rich has an active research program on rotating filtration, Taylor Couette flow, granular flow, fire suppression, and acoustics. He has five patents and over 40 refereed journal and proceedings papers along with many other articles, abstracts, and presentations.

Acknowledgments: Thanks to my talented and hard-working co-authors as well as the many colleagues and students who took the tutorial for a "test drive." Special thanks to Mike Minbiole for his major contributions to Graphics Concepts with SolidWorks. Thanks also to Northwestern University for the time to work on a book. Most of all, thanks to my loving wife, Maiya, and my children, Hannah and Kyle, for supporting me in this endeavor. (Photo courtesy of Evanston Photographic Studios, Inc.)



Jack Leifer is an Assistant Professor in the Department of Mechanical Engineering at the University of Kentucky Extended Campus Program in Paducah, and was previously with the Department of Mathematical Sciences and Engineering at the University of South Carolina—Aiken. He received his Ph.D. in Mechanical Engineering from the University of Texas at Austin in December 1995.

His current research interests include the modeling of sensors for manufacturing, and the use of Artificial Neural Networks to predict corrosion.

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David C. Kuncicky is a native Floridian. He earned his Baccalaureate in psychology, Master's in computer science, and Ph.D. in computer science from Florida State University. He has served as a faculty member in the Department of Electrical Engineering at the FAMU–FSU College of Engineering and the Department of Computer Science at Florida State University. He has taught computer science and computer engineering courses for over 15 years. He has published research in the areas of intelligent hybrid systems and neural networks. He is currently the Director of Engineering at Bioreason, Inc. in Sante Fe, New Mexico.

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Jim Steger is currently Chief Technical Officer and cofounder of an Internet applications company. He graduated with a Bachelor of Science degree in Mechanical Engineering from Northwestern University. His prior work included mechanical engineering assignments at Motorola and Acco Brands. At Motorola, Jim worked on part design for two-way radios and was one of the lead mechanical engineers on a cellular phone product line. At Acco Brands, Jim was the sole engineer on numerous office product designs. His Worx stapler has won design awards in the United States and in Europe. Jim has been a Pro/Engineer user for over six years.

Acknowledgments: Many thanks to my co-authors, especially Rich Lueptow for his leadership on this project. I would also like to thank my family for their continuous support.

David I. Schneider holds an A.B. degree from Oberlin College and a Ph.D. degree in Mathematics from MIT. He has taught for 34 years, primarily at the University of Maryland. Dr. Schneider has authored 28 books, with one-half of them computer programming books. He has developed three customized software packages that are supplied as supplements to over 55 mathematics textbooks. His involvement with computers dates back to 1962, when he programmed a special purpose computer at MIT's Lincoln Laboratory to correct errors in a communications system.

Michael T. Snyder is President of Internet startup Appointments123.com. He is a native of Chicago, and he received his Bachelor of Science degree in Mechanical Engineering from the University of Notre Dame. Mike also graduated with honors from Northwestern University's Kellogg Graduate School of Management in 1999 with his Masters of Management degree. Before Appointments123.com, Mike was a mechanical engineer in new product development for Motorola Cellular and Acco Office Products. He has received four patents for his mechanical design work. "Pro/Engineer was an invaluable design tool for me, and I am glad to help students learn the basics of Pro/Engineer."

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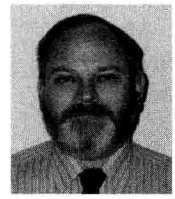

Stephen J. Chapman received a BS in Electrical Engineering from Louisiana State University (1975), an MSE in Electrical Engineering from the University of Central Florida (1979), and pursued further graduate studies at Rice University. Mr. Chapman is currently Manager of Technical Systems for British Aerospace Australia, in Melbourne, Australia. In this position, he provides technical direction and design authority for the work of younger engineers within the company. He is also continuing to teach at local universities on a part-time basis.

Mr. Chapman is a Senior Member of the Institute of Electrical and Electronics Engineers (and several of its component societies). He is also a member of the Association for Computing Machinery and the Institution of Engineers (Australia).

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1

Engineering Graphics

OVERVIEW

Engineering designs start as images in the mind's eye of an engineer. Engineering graphics has evolved to communicate and record these ideas on paper both two- and three-dimensionally. In the past few decades, the computer has made it possible to automate the creation of engineering graphics. Today engineering design and engineering graphics are inextricably connected. Engineering design is communicated visually using engineering graphics.

SECTIONS

- 1.1 The Importance of Engineering Graphics
- 1.2 Engineering Graphics
- 1.3 CAD
- 1.4 Design and CAD

OBJECTIVES

After reading this chapter, you should be able to:

- Describe visual thinking
- Differentiate perspective, isometric, and orthographic projections
- Understand the basis of CAD
- Understand the relationship between design and CAD

1.1 THE IMPORTANCE OF ENGINEERING GRAPHICS

"Visualizing" a picture or image in your mind is a familiar experience. The image can be visualized at many different levels of abstraction. Think about light and you might see the image of a light bulb in your "mind's eye." Alternatively, you might think about light versus dark. Or you might visualize a flashlight or table lamp. Such visual thinking is necessary in engineering and science. Albert Einstein said that he rarely thought in words. Instead, he laboriously translated his visual images into verbal and mathematical terms.

Visual thinking is a foundation of engineering. Walter P. Chrysler, founder of the automobile company, recounted his experience as an apprentice machinist where he built a model locomotive that existed "within my mind so real, so complete, that it seemed to have three dimensions there."

Yet, the complexity of today's technology rarely permits a single person to build a device from his own visual image. The images must be conveyed to other engineers and designers. In addition, those images must be constructed in such a way that they are in a readily recognizable, consistent, and readable format. This assuress that the visual ideas are clearly and unambiguously conveyed to others. *Engineering graphics* is a highly stylized way of presenting images of parts or assemblies.

A major portion of engineering information is recorded and transmitted using engineering graphics. In fact, 92 percent of the design process is graphically based. Written and verbal communications along with mathematics account for the remaining eight percent. To demonstrate the effectiveness of engineering graphics compared to a written description try to visualize an ice scraper based on this word description:

> An ice scraper is generally in the shape of a 140 × 80 × 10 mm rectangular prism. One end is beveled from zero thickness to the maximum thickness in a length of 40 mm to form a sharp edge. The opposite end is semicircular. A 20 mm diameter hole is positioned so the center of the hole is 40 mm from the semicircular end and 40 mm from either side of the scraper.

It is evident immediately that the shape of the ice scraper is much more easily visualized from the graphical representation shown in Figure 1.1 than from the word description. Humans grasp information much more quickly when that information is presented in a graphical or visual form rather than as a word description.

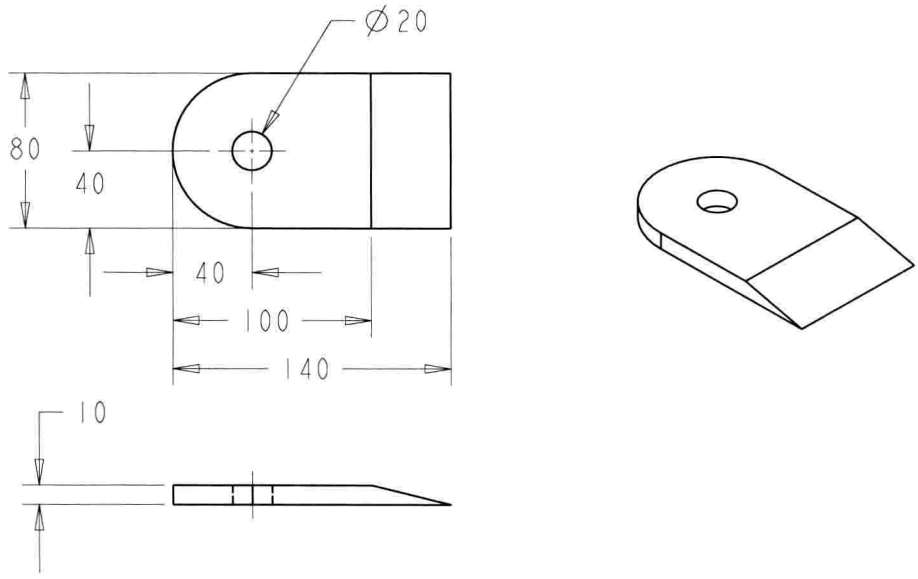

Figure 1.1.

Engineering drawings, whether done using a pencil and paper or a computer, start with a blank page or screen. The engineer's mind's eye image must be transferred to the paper or computer screen. The creative nature of this activity is similar to that of an artist. Perhaps the greatest example of this is Leonardo da Vinci, who had exceptional engineering creativity devising items such as parachutes and ball bearings, shown in Figure 1.2, hundreds of years before they were re-invented. He also had exceptional artistic talent, creating some of the most famous pictures ever painted such as *Mona Lisa* and *The Last Supper.*

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