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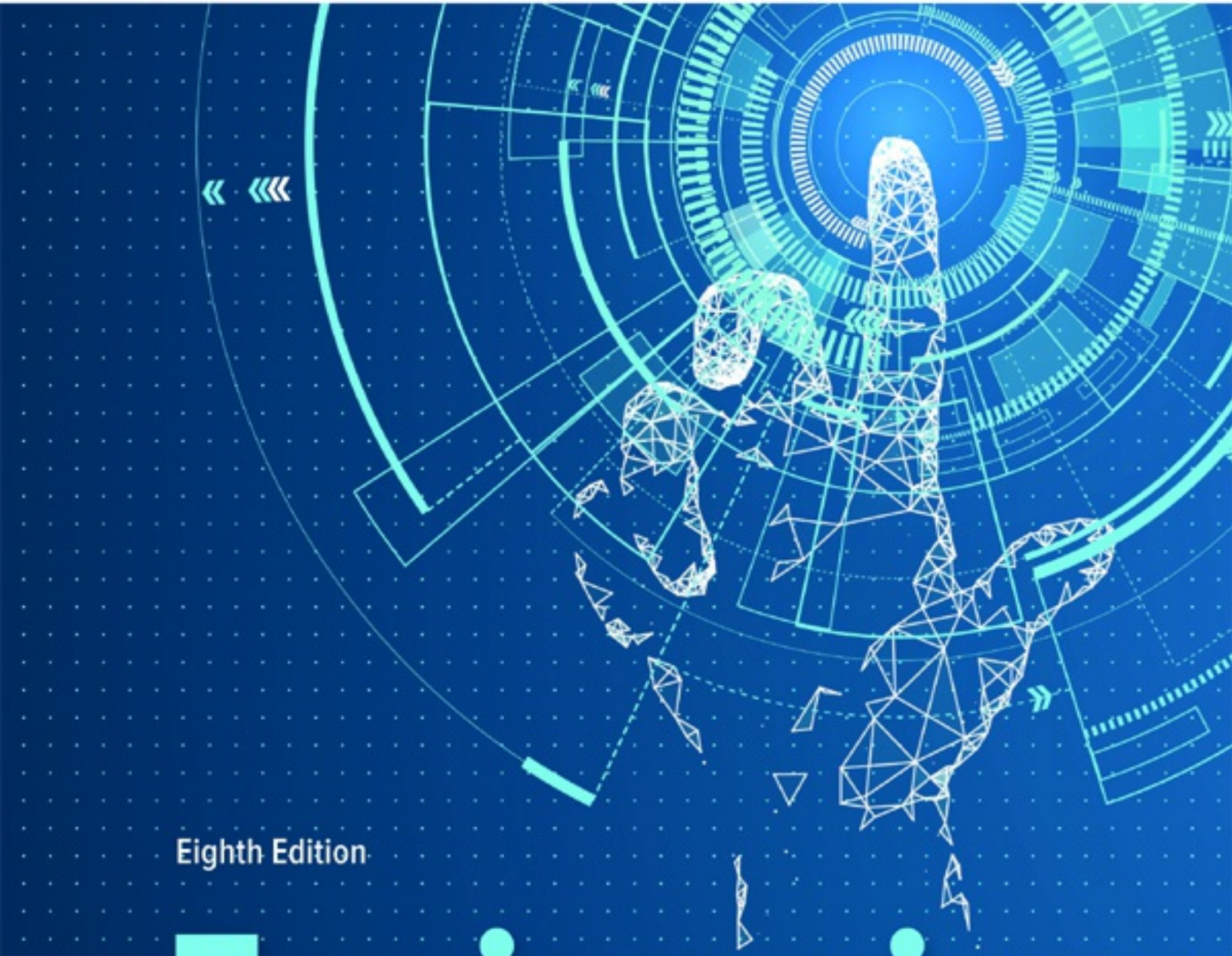

Eighth Edition

Engineering

Fundamentals and Problem Solving

Arvid R. Eide • Steven K. Mickelson • Cheryl L. Eide
Roland D. Jenison • Larry L. Northup

Mc Graw Hill

Engineering Fundamentals & Problem Solving

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Preface

To the Student

As you begin the study of engineering no doubt you are filled with enthusiasm, curiosity, and a desire to succeed. Your first year will be spent primarily in establishing a solid foundation in mathematics, basic sciences, and communications. Also, you will be introduced to selected engineering topics that will demonstrate how engineers approach problem solving, arrive at correct solutions, and interface with other engineering professionals and the general public to implement the solutions. You will see how mathematics, science, and communications provide the means to solve problems and convey the solutions in a manner that can be clearly understood and quickly verified by the appropriate persons. Next, you will discover the need for more in-depth study in many engineering subjects in order to solve increasingly complex problems. We believe the material presented in this book will provide you with a fundamental understanding of how engineers function in today's technological world. After your study of topics in this text, we believe you will be eager to enter the advanced engineering subjects in your chosen discipline, confident that you will successfully achieve your educational goals. You will also find profiles of practicing engineers who were in your shoes a few years ago. They will show the result of your hard work will result in amazing careers.

To the Instructor

Engineering courses for first-year students cover a wide range of

topics from an overview of the engineering profession to discipline-specific subjects. A broad set of course goals, including coverage of prerequisite material, motivation, and retention, have spawned a variety of first-year activity. Courses in introductory engineering and problem solving routinely utilize spreadsheets and mathematical solvers in addition to teaching the rudiments of a computer language. The Internet has become a major instructional tool, providing a wealth of data to supplement your class notes and textbooks. This eighth edition continues the authors' intent to introduce the profession of engineering and to provide students with many of the tools and techniques needed to succeed.

The eighth edition of this text draws on the experiences the authors have encountered with the first seven editions and incorporates many excellent suggestions from faculty and students using the text. Over the past 40+ years the fundamentals of problem solving have remained nearly the same, but the numerical tools and presentation techniques have improved tremendously. Therefore our general objectives remain the same for this eighth edition, and we have concentrated on new and emerging problems like microplastics pollution and desalination of water for drinking and community use and improvements in the textual material.

The objectives are (1) to motivate engineering students during their first year when exposure to the subject matter of engineering is limited, (2) to provide students with experience in solving problems in both SI and customary units while presenting solutions in a logical manner, (3) to introduce students to subject areas common to most engineering disciplines that require the application of fundamental engineering concepts, and (4) to develop students' skills in solving open-ended problems.

The material in this book is presented in a manner that allows each of you to emphasize certain aspects more than others without loss of continuity. In the eighth edition, new engineering graduate profiles have been added to help student understand better what an engineer

does and what recommendations they would have for a new engineering student. Modern engineering examples, data, and photos have been integrated throughout the chapters, and more problems have been added to Connect. The problems that follow most chapters vary in difficulty so that students can experience success rather quickly and still be challenged as problems become more complex.

There is sufficient material in the 18 chapters for a three-credit semester course. By omitting some chapters and/or by varying coverage from term to term, you can present a sound introductory problem-solving course in two to four quarter credits or two semester credits.

The book may be visualized as having three major sections. The first, encompassing the first three chapters, is an introduction to the engineering profession. Chapter 1 provides information on engineering disciplines and functions. If a formal orientation course is given separately, Chapter 1 can be simply a reading assignment and the basis for students to investigate disciplines of interest. Chapter 2 outlines the course of study and preparation for an engineering work environment. Interdisciplinary projects, teaming, and ethics are discussed. Chapter 3 is an introduction to the design process. If time permits, this material can be supplemented with case studies and your personal experiences to provide an interesting and motivating look at engineering.

The second major section, Processing Engineering Data, includes materials we believe that all engineering students require in preparation for success in the engineering profession. Chapters 4 and 5 provide procedures for approaching an engineering problem, determining the necessary data and method of solution, and presenting the results. The authors have found that emphasis in this area will reap benefits when the material and problems become more difficult later.

Chapters 6 and 7 include engineering estimations and dimensions and units (including both customary and SI units). Throughout the book discussions and example problems tend to emphasize SI metric. However, other dimension systems are used extensively today, so a number of our examples and problems contain nonmetric units to ensure that students are exposed to conversions and other units that

are commonly used.

Chapters 8 and 9, Engineering Economy, demonstrate the importance of understanding the time value of money in making engineering decisions. Chapter 8 emphasizes basic calculations using everyday information such as credit card debt, savings accounts, and current interest rates. Additionally, the Summary Table 8.8 is a valuable resource that students use well beyond this course. Chapter 9 follows with applications to engineering decision making for equipment selection, depreciation, investments, and taxes. Chapters 10 and 11, Statistics, provide an introduction to a subject that is assuming a greater role in engineering decision making. Chapter 10 introduces basic descriptive statistics, linear regression, and coefficient of correlation. Chapter 11 includes normal distributions as well as *Student's t, F*, and *Chi-Square*. It also adds new material on the use of inferential statistics and a general introduction to randomized sampling and experimental design. The ability to take large amounts of test or field data, perform statistical analyses, and draw correct conclusions is crucial in establishing performance parameters. Engineering Economy and Statistics are subdivided, permitting you to choose the first chapter for an introduction to the fundamentals and, if time permits, applications to specific engineering activities can be covered.

The third major section provides engineering content that you can use to reinforce fundamentals from the previous section. Chapters 12 through 17 allow you as an instructor a great deal of flexibility. Chapters 12 and 13 on engineering mechanics provide an introduction to statics and strength of materials. Force vectors, two-dimensional force systems, and the conditions of equilibrium are emphasized in Chapter 12. Chapter 13 emphasizes stresses and strains and requires Chapter 12 as a prerequisite. Chapter 15 has undergone significant updating. Chapter 15 discusses energy forms and sources. The authors believe that engineering students need to become aware of the world's current dependence on fossil fuels very early in their studies so they

may apply this knowledge to the use and development of alternative sources of energy.

Chapter 16 follows with an introduction to thermodynamics and applications of the First and Second Laws of Thermodynamics. The study of Chapter 16 should be preceded by coverage of Chapter 15.

Chapter 14, Material Balance, and Chapter 17, Electrical Theory, complete the third major section and contain upgraded example problems.

Certain problems suggest the use of a computer or spreadsheet for solution. These are open-ended or "what-if" problems. Depending on the students' prior work with programming or spreadsheets, additional instruction may be required before attempting these problems. Chapter 18 covers the use of flowcharts, which can be of tremendous help when programming with all kinds of computer languages.

The appendices are provided as a ready reference on selected areas that will enable students to review topics from algebra and trigonometry. The National Society of Professional Engineers' Code of Ethics for Engineers is included and is highly recommended for reading and class discussion. Other appendices include tables, unit conversions, formulas, and selected answers to chapter problems.

Because the text was written for first-year engineering students, mathematical expertise beyond algebra, trigonometry, and analytical geometry is not required for any material in the book. The authors have found, however, that additional experience in pre-calculus mathematics is very helpful as a prerequisite for this text.

Acknowledgments

The authors are indebted to many who assisted in the development of this edition of the textbook. First, we would like to thank the faculty of the former Division of Engineering Fundamentals and Multidisciplinary Design at Iowa State University, who have taught the engineering computations courses over the past 40+ years. They, with the support of engineering faculty from other departments, have made the courses a success by their efforts. Several thousands of students have taken the courses, and we want to thank them for their comments and ideas, which have influenced this edition. The many suggestions of

faculty and students alike have provided us with much information that was necessary to improve the previous editions. Special thanks go to the reviewers for this edition whose suggestions were extremely valuable. These suggestions greatly shaped the manuscript in preparation of the eighth edition.

Finally, we thank our families for their continuing support of our efforts.

Arvid R. Eide
Steven K. Mickelson
Cheryl L. Eide
Roland D. Jenison
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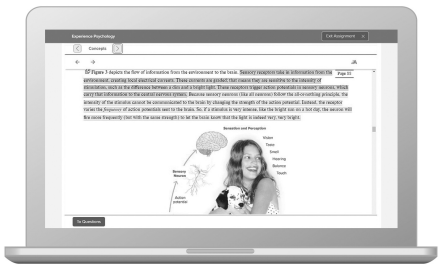

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About the Authors

Arvid R. Eide received his baccalaureate degree in mechanical engineering from Iowa State University. Upon graduation he spent two years in the U.S. Army as a commissioned officer and then returned to Iowa State as an instructor while completing a master's degree in mechanical engineering. Professor Eide has worked for Western Electric, John Deere, and the Trane Company. He received his Ph.D. in 1974 and was appointed professor and Chair of Freshman Engineering, a position he held from 1974 to 1989, at which time Dr. Eide was appointed Associate Dean of Academic Affairs. In 1996, he returned to teaching as a professor of mechanical engineering. In January 2000 he retired from Iowa State University as professor emeritus of mechanical engineering.

Steven K. Mickelson is the Chuck R. and Jane F. Olsen Professor of Engineering at Iowa State University. His tenure home is in the Department of Agricultural and Biosystems Engineering (ABE). Dr. Mickelson was the Chair for the ABE department from 2011 to 2021. He is currently the Special Advisor to the Senior Vice President and Provost, co-leading the roleout of Iowa State University's new student information and receivable system. His teaching specialties include computer-aided graphics, engineering problem solving, engineering design, and soil and water conservation engineering. His research areas include evaluation of best management practices for reducing surface and groundwater contamination, manure management evaluation for environmental protection of water resources, and the scholarship of teaching and learning. Dr. Mickelson has been very

active in the American Society for Engineering Education and the American Society of Agricultural and Biosystems Engineers for the past 40 years. He received his agricultural engineering degrees from Iowa State University in 1982, 1984, and 1991. He is a fellow within the American Society for Agricultural and Biological Engineers.

Cheryl L. Eide has worked with undergraduate student recruitment, retention, advising, and the development of programs to support women and minorities pursuing engineering. Her teaching portfolio includes engineering fundamentals and problem solving, engineering economy, material handling, factory layout, and computer simulation. Dr. Eide helped to re-activate and charter the Heart of Iowa Section of the Society of Women Engineers (SWE) and served as the faculty advisor to the Iowa State SWE student section. She is a member of the Cardinal Key Honor Society, which recognizes outstanding leadership, character, service, and scholarship at Iowa State University where Dr. Eide earned her bachelor's, master's, and doctorate degrees.

Roland D. (Rollie) Jenison taught for 35 years in aerospace engineering and lower-division general engineering. He taught courses in engineering problem solving, engineering design graphics, aircraft performance, and aircraft stability and control, in addition to serving as academic adviser to many engineering students. He was a member of the American Society for Engineering Education (ASEE) and the American Institute of Aeronautics and Astronautics (AIAA), and published numerous papers on engineering education. He served as chair of the Engineering Design Graphics Division of ASEE in 1986–1987. He was active in the development of improved teaching methodologies through the application of team learning, hands-on projects, and open-ended problem solving. He retired in June 2000 as professor emeritus in the Department of Aerospace Engineering and Engineering Mechanics at Iowa State University.

Larry L. Northup is a professor emeritus of civil, construction, and environmental engineering at Iowa State University. He has 40 years of teaching experience, with 25 years devoted to lower-division

engineering courses in problem solving, graphics, and design. He has two years of industrial experience and is a registered engineer in Iowa. He has been active in ASEE (Engineering Design Graphics Division), having served as chair of the Freshman Year Committee and Director of Technical and Professional Committees (1981–1984). He also served as chair of the Freshman Programs Constituent Committee of ASEE in 1983–1984.

CHAPTER **1**

The Engineering Profession

Chapter Objectives

When you complete your study of this chapter, you will be able to:

- Understand the role of engineering in the world
- Understand how to prepare for a meaningful engineering career
- Understand the role of an engineer in the engineering workplace
- Describe the responsibilities and roles of the most common engineering disciplines
- Gain academic career advice from past engineering graduates from various engineering disciplines

1.1 An Engineering Career

The rapidly expanding and developing sphere of science and

technology may seem overwhelming to the individual exploring a career in a technological field. A technical specialist today may be called engineer, scientist, technologist, or technician, depending on education, industrial affiliation, and specific work. For example, about 700 colleges and universities in 29 countries offer close to 3 600 engineering programs accredited by ABET, the main accrediting body for engineering and technology programs. Included in these programs are such traditional specialties as aerospace, agricultural, architectural, chemical, civil, computer, construction, electrical, industrial, manufacturing, materials, mechanical, and software engineering—as well as expanding bioengineering, biomedical, biological, electromechanical, environmental, and telecommunications. Programs in engineering, mechanics, mining, nuclear, ceramic, software, and petroleum engineering add to a lengthy list of career options in engineering alone. Coupled with thousands of programs in science and technical training offered at hundreds of universities, colleges, and technical schools, the task of choosing the right field no doubt seems formidable (Figure 1.1).

Figure 1.1 Imagine the number of engineers who were involved in the design of the windmill related to construction, material choices, electrical systems, and mechanical systems.

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Since you are reading this book, we assume that you are interested in studying engineering or at least are trying to decide whether to do so. Up to this point in your academic life you probably have had little experience with engineering as a career and have gathered your

impressions from advertising materials, counselors, educators, and perhaps a practicing engineer or two. Now you must investigate as many careers as you can as soon as possible to be sure of making the right choice.

The study of engineering requires a strong background in mathematics and the physical sciences. Section 1.5 discusses typical areas of study within an engineering program that lead to the bachelor's degree. You also should consult with your academic counselor about specific course requirements. If you are enrolled in an engineering program but have not chosen a specific discipline, consult with an adviser or someone on the engineering faculty about particular course requirements in your areas of interest.

When considering a career in engineering or any closely related fields, you should explore the answers to several questions:

- What is engineering?
- What are the career opportunities for engineers?
- What are the engineering disciplines?
- Where does the engineer fit into the technical spectrum?
- How are engineers educated?
- What is meant by professionalism and engineering ethics?
- What have engineers done in the past?
- What are engineers doing now? What will engineers do in the future?
- What are the workplace competencies needed to be a successful engineer?