Foundations of Engineering

Mark T. Holtzapple • W. Dan Reece

Foundations of ENGINEERING

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TO THE PROFESSOR

Traditional engineering courses—such as courses on heat transfer, circuits, and fluids—are fairly well defined. In contrast, there is no general agreement on the content of freshman engineering courses. Current freshman engineering texts choose from a range of topics including professionalism, creativity, ethics, design, technical writing, graphing, systems of units, engineering science, and problem solving. All of these topics are important aspects of the freshman engineering experience, but we found no one text that adequately encompassed them all. Therefore, we decided to write our own text to fill the void.

Many freshman engineering texts describe specific engineering disciplines, such as mechanical or electrical engineering, and give sample problems involving statics or electrical circuits. Given the increasing number of new engineering disciplines (e.g., biochemical engineering) and the increasingly interdisciplinary nature of engineering (e.g., mechatronics), we feel this discipline-specific approach is inadequate. Instead, we feel a more unified approach is required, with less emphasis on traditional disciplines. The goals of our text are listed here:

- *Excite the student about engineering.* Most practicing engineers find their work to be very exciting and creative. However, freshmen must struggle with the rigors of their science and mathematics classes, so they may be unaware of the pleasures that await them. We hope to stimulate the students' interest in engineering by describing engineering history, challenging them with "brain teaser" problems, and explaining the creative process.
- *Provide a strong foundation in engineering fundamentals.* Engineering has grown beyond the traditional disciplines (e.g., civil, mechanical, and electrical engineering) and now includes nontraditional disciplines (e.g., biomedical, environmental, and nuclear engineering). The common threads through all these disciplines are fundamental physical and mathematical laws.
- *Cultivate problem-solving skills.* The most important engineering skill is the ability to solve problems. We describe many heuristic approaches to creative problem solving as well as a systematic approach to solving well-defined engineering problems.
- *Challenge advanced students.* Students who have good high school backgrounds will have been exposed to calculus and physics. To stimulate their interest in engineering, advanced topics are sprinkled throughout the book.
- *Integrate computing with other engineering topics.* This book contains numerous sample computer programs illustrating a variety of engineering applications. This will help

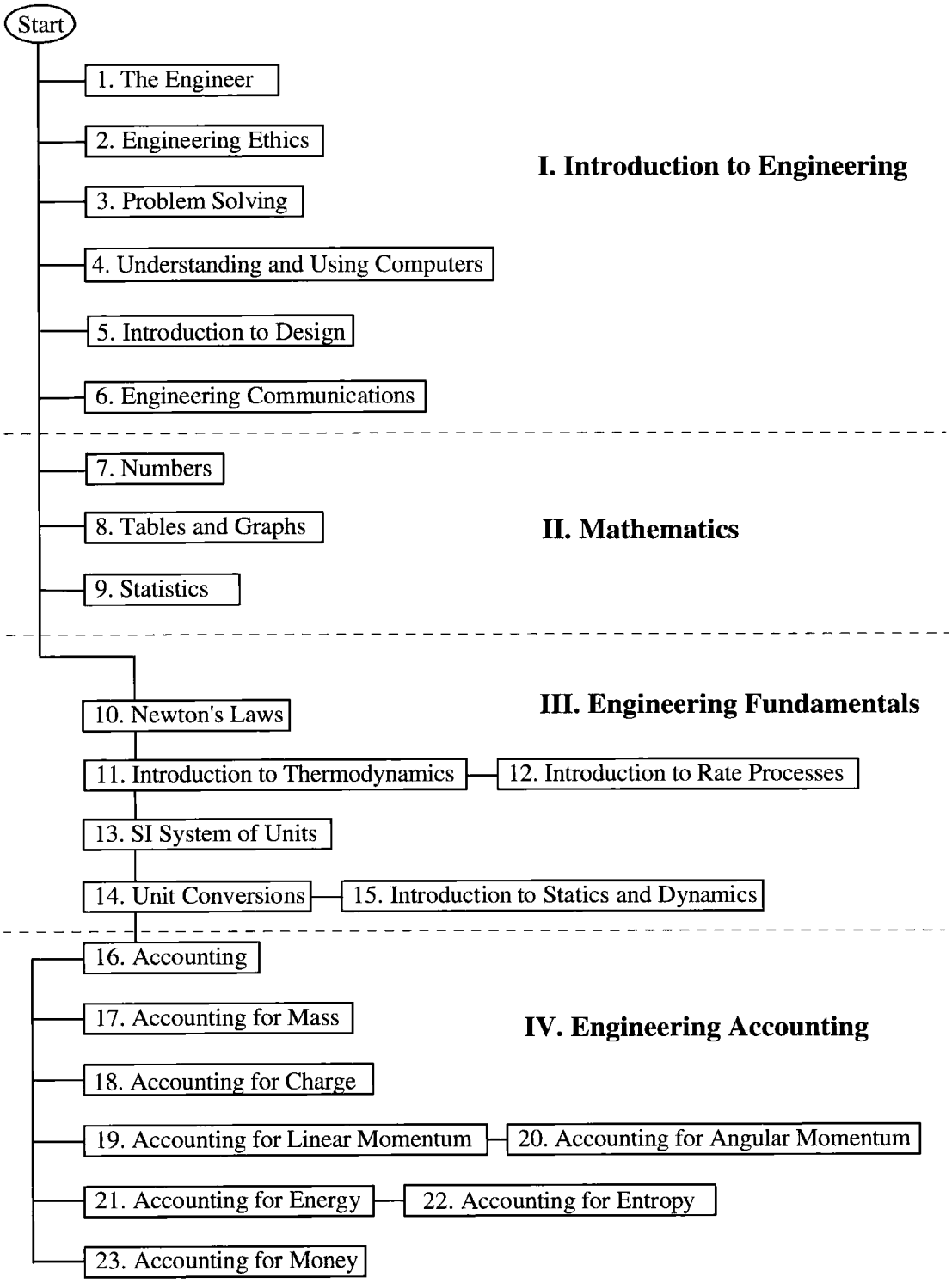
the student realize that computing is not a separate topic, but is a tool used by engineers to solve problems.

- *Provide reference material.* Most students will not purchase handbooks until later in their engineering careers. This book provides unit conversion factors and material properties so that students have the resources to solve real-world problems.
- *Provide information the student is unlikely to encounter elsewhere.* Often, important engineering information that does not fit neatly into advanced courses is put into a freshman engineering course. Thus, this text includes information such as statistics, grammatical rules for the SI system, and graphing rules.
- *Connect with their high school experience.* Many students may be concerned about possible gaps between their actual knowledge and the knowledge college professors expect of them. Touching upon topics with which they are already familiar will ease their anxiety and improve their confidence.
- *Connect with their freshman science and mathematics courses.* Some students may perceive that their freshman science and mathematics classes are a hazing process, and may not understand that these courses form the backbone of engineering. We purposely incorporate topics they see in other courses to show the connection with engineering.
- *Provide "soak time" for difficult topics.* Learning is a process that requires repetition. A few difficult topics that students will encounter in later engineering courses (e.g., thermodynamics, rate processes) are introduced here at a very simple level. This allows them to become acquainted with the ideas, so their next detailed exposure is easier.
- *Introduce the design process.* To help freshmen experience the joy of engineering, we think it is necessary to assign a design problem during their first semester. To support this notion, early in the text, we introduce design.
- *Emphasize the importance of communication skills.* Too often, engineers are criticized for lacking communication skills. To help overcome this problem, we provide information on both oral and written communication that will be immediately useful to freshmen during their design project.

The topics in *Foundations of Engineering* are presented in a sequential manner, so it can be read from front cover to back cover with each new topic building on previously presented topics. Although the book is designed so that it **can** be read from cover to cover, this does not imply that it **must** be read from cover to cover. The accompanying figure indicates how the chapters fit together.

The "road map" in the accompanying figure shows that Chapters 1 through 9 are independent; if you decide to skip these chapters, it will not seriously affect the students' understanding of later chapters. In contrast, Chapters 10, 11, 13, and 14 are interdependent and must be covered in sequence. Chapters 12 and 15 are optional, but if covered, they must be after Chapters 11 and 14, respectively. Chapter 16 sets the stage for all the later chapters and therefore must be covered if the later chapters are taught. Chapters 17, 18, 19, 21, and 23 are independent. If Chapters 20 and 22 are covered, they must be done after Chapters 19 and 21, respectively.

In our experience, many students who have the potential to make excellent engineers have a poor command of high school mathematics. Whether they have forgotten it or never learned it, the information is lost to them because they no longer have their high school



Relationship of book chapters.

mathematics texts. To overcome this problem, we have prepared *Mathematics Supplement to Foundations of Engineering,* which reviews high school mathematics. We strongly recommend that you make this text available to your students, by making it either required or optional. At Texas A&M, we require students to do homework problems from the supplemental text, but do not take class time to discuss these topics because they review high school material.

If your freshman engineering course is taught in two semesters, it is possible to use the entire book. However, if you are teaching a one-semester course, it is unlikely you will be able to cover all the material. In this case, we suggest that you give the students a "guide map" through the book, indicating which sections you consider to be core testable material and which sections are offered for enrichment purposes only. All the sections are conveniently numbered, so it is possible to be very explicit about what you expect the students to read.

This book is designed to be used in conjunction with a computer programming text. There are computer problems in almost every chapter that can be used to integrate students' computing knowledge with other engineering topics. Also, this book may be used in conjunction with an engineering graphics text. Obviously one of the most important tools for practicing engineers is the ability to read and create engineering drawings. We mention the importance of graphics several places in our text, but provide no real examples because this subject is very broad and is covered very well by other texts.

McGraw-Hill maintains a website at www.mhhe.com/engcs/general/holtzapple/instructor/olc/, that provides supplemental teaching materials. Please visit the site; we're sure you'll find it useful.

We hope that you and your students enjoy using this book. We will happily receive suggestions for improvements that may be incorporated into future editions.

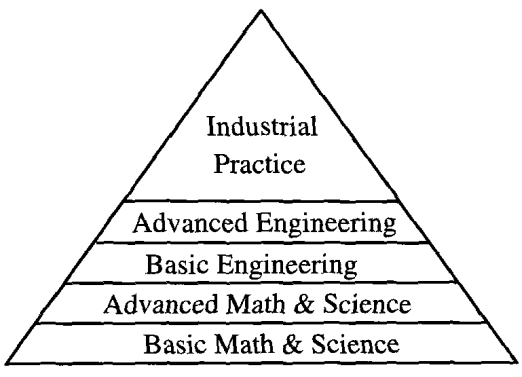
Mark T. Holtzapple W. Dan Reece

TO THE STUDENT

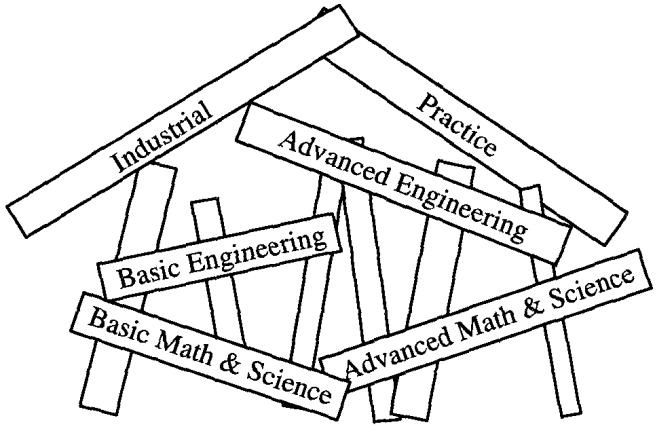
The engineering profession blossomed in Egypt with the construction of irrigation systems, roads, and pyramids by the first civil engineers. Regardless of the engineering discipline you decide to follow, you can visualize your engineering studies as a construction project in which you are building your knowledge.

If you are wise, you will construct a pyramid. It is a well-proven structure that can withstand millennia of weathering. A pyramid is strong because it has a wide foundation. Your wide foundation requires a firm grasp of mathematics and science, which cannot be achieved by memorizing formulas or learning rote procedures. Instead, your objective should be to become "educated" and to *understand.*

Unfortunately, some students take the "plug-and-chug" approach to their engineering studies. They mistakenly believe that real-world engineers mindlessly plug numbers into handbook formulas with little understanding of the underlying principles. They view the required science and mathematics courses as a hazing process to separate the weak from the strong. Students with this attitude are constructing a rickety shack that will blow down in the first strong wind. They will be incapable of solving difficult problems and probably will make no significant contributions to society.



The Educated Engineer



The "Plug-and-Chug" Engineer

In writing this text, our purpose is to begin your engineering education by providing a firm foundation for your later studies. This is a huge task, so our book is necessarily long and detailed. In fact, it is unlikely that you will be able to cover the entire book in a single semester. Your professor will decide which of the many topics will be covered in your particular course. However, your professor's decisions should not preclude you from reading on your own. All of the topics in this text should be covered at some point in your studies.

We have divided the book into four sections:

- *Introduction to Engineering:* This is an overview of the engineering professions and the skills required to become a good engineer.
- *Mathematics*: We touch on a few mathematical concepts that you are not likely to encounter in your calculus class.
- *Engineering Fundamentals*: We feel the topics discussed here are absolutely fundamental to engineering education. You will be introduced to topics such as thermodynamics, rate processes (e.g., heat transfer, electricity), and Newton's laws. Unit conversions are given particular attention because this topic is so important.
- *Engineering Accounting*: We have cast the basic conservation laws (e.g., conservation of energy or mass) as a simple "accounting" procedure. We feel that accounting is a unifying concept that transcends the individual engineering disciplines. Here, you have the opportunity to apply your new skills to a variety of problems. The fundamental accounting principles are applied to such quantities as mass, energy, linear momentum, and angular momentum.

In case your high school mathematics is rusty, we offer a sister text called *Mathematics Supplement to Foundations of Engineering*. This text reviews topics such as algebra, mathematical notation, geometry, trigonometry, logarithms, polynomials, zeros of equations, and calculus. In addition to the mathematics supplement, McGraw-Hill maintains a website at www.mhhe.com/engcs/general/holtzapple/student/olc/, that contains useful supplemental learning materials. Please visit the site; we're sure you'll find it useful.

We think of our book as a smorgasbord of delightful delicacies. There are so many delicacies, it is impossible for you to eat them all in a single sitting. However, with many sittings, it is possible for you to enjoy them all.

As many topics as we cover in this book, we still do not attempt to cover everything you will need to know. For several topics of major importance to engineers, particularly engineering graphics and the details of computing, we expect that you are receiving training from other texts. Both topics are essential to the practicing engineer. Even a simple engineering drawing passes more information than several volumes of words alone. Computers have revolutionized engineering. What took hours of drudgery just 20 years ago can now be done in seconds using personal computers and software.

As shown in the "pyramid of learning" depicted earlier, all engineering disciplines use knowledge gained in mathematics and science courses. In addition, an important foundation of engineering is communications. One of the most important functions of an engineer is to present his or her findings clearly and succinctly, both orally or in writing. It is no accident that English and technical writing are included in your engineering studies! The ability to convey ideas well comes only with hard work, practice, and constructive feedback; this may be the most important skill you have to learn.

We recommend that you hold onto this book. It has many useful charts, tables, conversion factors, and formulas that you will find invaluable in your later studies. Also, the topics are covered in a friendly, unified approach. If you are having troubles grasping a concept in your later studies, we hope you will take this book off your shelf and read—or reread—the appropriate chapters.

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ACKNOWLEDGMENTS

A project of this size cannot be completed without assistance from many individuals. Dan Turner, the undergraduate dean at the Dwight Look College of Engineering at Texas A&M, initiated this project to provide a text for our introductory engineering course *Engineering Problem Solving and Computing*. He provided financial support and organized internal reviews of the manuscript. Karan Watson, who followed Dan Turner, provided invaluable support and encouragement for this project.

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As mentioned earlier, Dan Turner organized a review of the manuscript by the following individuals: Lee Carlson, Glen Williams, Mac Lively, Alberto Garcia, Larry Piper, Skip Fletcher, Ray James, Tom Tielking, Make McDermott, Ron Hart, Richard Griffin, Gerald Miller, Pierce Cantrell, Aaron Cohen, Vincent Sweat, and Kaylan Annamalai. We are grateful for their helpful comments.

It took thousands of hours to write this book, mostly during the evenings and weekends. We thank our families for graciously providing us with this time.

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ABOUT THE AUTHORS

Mark T. Holtzapple

Mark T. Holtzapple is Professor of Chemical Engineering at Texas A&M University. In 1978, he received his B.S. in chemical engineering from Cornell University. In 1981, he received his Ph.D. from the University of Pennsylvania. His Ph.D. research focused on developing a process to convert fast-growing poplar trees into ethanol fuel.

After completing his formal education, in 1981 Mark joined the U.S. Army and helped develop a portable backpack cooling device to alleviate heat stress in soldiers wearing chemical protective clothing.

After completing his military service, in 1986 Mark joined the Department of Chemical Engineering at Texas A&M University. It quickly became apparent that he had a passion for teaching: within a two-year period he won nearly every major teaching award offered at Texas A&M including Tenneco Meritorious Teaching Award, General Dynamics Excellence in Teaching Award, Dow Excellence in Teaching Award, and two awards offered by the Texas A&M Association of Former Students. Mark particularly has a passion for teaching freshman engineering students. He wrote this book to excite students about engineering and to help lay a solid foundation for their future studies.

In addition to his role as an educator, Mark is a prolific inventor. He is developing an energy-efficient, ecologically friendly air-conditioning system that uses water instead of Freons as the working fluid. He is also developing a high-efficiency, low-pollution Brayton cycle engine suitable for automotive use. In addition, he is developing technologies for converting waste biomass into useful products, such as animal feeds, industrial chemicals, and fuels. To recognize his contributions in biomass conversion, in 1996 he received the Presidential Green Chemistry Challenge Award offered by the president and vice president of the United States.

W. D. Reece

Dr. Reece is an Associate Professor in the Nuclear Engineering Department and Director of the Nuclear Science Center at Texas A&M. He received his Bachelor of Chemical Engineering, Master of Science in Nuclear Engineering, and Ph.D. in Mechanical Engineering all at the Georgia Institute of Technology. He has worked as an analytical chemist, a chemical engineer, and a staff scientist at the Pacific Northwest National Laboratory, before his current positions at Texas A&M.

Much of Dr. Reece's research is in the area of radiation monitoring, novel uses of radiation in medicine, and the health effects of radiation. Like Dr. Holtzapple, he has a passion for teaching and has won a Distinguished Teaching Award from the Texas A&M Association of Former Students. Dr. Reece teaches many topical courses in dosimetry and Health Physics, has an active consulting business, and, whenever his schedule allows him free time, enjoys backpacking, playing tennis, and running. His greatest enjoyment comes from his children, his students, and the advances in medicine and worker protection he has helped to make.

WHY THIS BOOK SHOULD BECOME A PART OF YOUR ENGINEERING LIBRARY

- It makes difficult subjects accessible
- It will help you prepare for the professional engineering exam
- It provides useful reference information
- It makes an excellent supplemental resource for your later classes
- It provides a concise style guide for effective engineering communications
- It uses an engineering accounting framework to help you become more versatile
- It provides interesting historical vignettes

CONTENTS

SECTION TWO:

MATHEMATICS 188

SECTION THREE:

ENGINEERING FUNDAMENTALS 244