SI EDITION

SAEED MOAVENI

# Engineering Fundamentals

## AN INTRODUCTION TO ENGINEERING

FIFTH EDITION

## CONVERSIONS BETWEEN U.S. CUSTOMARY UNITS AND SI UNITS

| U.S. Customary unit | | Times conversion factor: Accurate | Times conversion factor: Practical | Equals SI unit | |
|---|---|---|---|---|---|
| **Acceleration (linear)** | | | | | |
| foot per second squared | $ft/s^2$ | 0.3048* | 0.305 | meter per second squared | $m/s^2$ |
| inch per second squared | $in./s^2$ | 0.0254* | 0.0254 | meter per second squared | $m/s^2$ |
| **Area** | | | | | |
| circular mil | cmil | 0.0005067 | 0.0005 | square millimeter | $mm^2$ |
| square foot | $ft^2$ | 0.09290304* | 0.0929 | square meter | $m^2$ |
| square inch | $in.^2$ | 645.16* | 645 | square millimeter | $mm^2$ |
| **Density (mass)** | | | | | |
| slug per cubic foot | $slug/ft^3$ | 515.379 | 515 | kilogram per cubic meter | $kg/m^3$ |
| **Density (weight)** | | | | | |
| pound per cubic foot | $lb/ft^3$ | 157.087 | 157 | newton per cubic meter | $N/m^3$ |
| pound per cubic inch | $lb/in.^3$ | 271.447 | 271 | kilonewton per cubic meter | $kN/m^3$ |
| **Energy; work** | | | | | |
| foot-pound | ft-lb | 1.35582 | 1.36 | joule (N·m) | J |
| inch-pound | in.-lb | 0.112985 | 0.113 | joule | J |
| kilowatt-hour | kWh | 3.6* | 3.6 | megajoule | MJ |
| British thermal unit | Btu | 1055.06 | 1055 | joule | J |
| **Force** | | | | | |
| pound | lb | 4.44822 | 4.45 | newton ($kg \cdot m/s^2$) | N |
| kip (1000 pounds) | k | 4.44822 | 4.45 | kilonewton | kN |
| **Force per unit length** | | | | | |
| pound per foot | lb/ft | 14.5939 | 14.6 | newton per meter | N/m |
| pound per inch | lb/in. | 175.127 | 175 | newton per meter | N/m |
| kip per foot | k/ft | 14.5939 | 14.6 | kilonewton per meter | kN/m |
| kip per inch | k/in. | 175.127 | 175 | kilonewton per meter | kN/m |
| **Length** | | | | | |
| foot | ft | 0.3048* | 0.305 | meter | m |
| inch | in. | 25.4* | 25.4 | millimeter | mm |
| mile | mi | 1.609344* | 1.61 | kilometer | km |
| **Mass** | | | | | |
| slug | $lb\text{-}s^2/ft$ | 14.5939 | 14.6 | kilogram | kg |
| **Moment of a force; torque** | | | | | |
| pound-foot | lb-ft | 1.35582 | 1.36 | newton meter | N·m |
| pound-inch | lb-in. | 0.112985 | 0.113 | newton meter | N·m |
| kip-foot | k-ft | 1.35582 | 1.36 | kilonewton meter | kN·m |
| kip-inch | k-in. | 0.112985 | 0.113 | kilonewton meter | kN·m |

## CONVERSIONS BETWEEN U.S. CUSTOMARY UNITS AND SI UNITS (Continued)

| U.S. Customary unit | | Times conversion factor: Accurate | Times conversion factor: Practical | Equals SI unit | |
|---|---|---|---|---|---|
| Moment of inertia (area) | | | | | |
| inch to fourth power | in.$^4$ | 416,231 | 416,000 | millimeter to fourth power | mm$^4$ |
| inch to fourth power | in.$^4$ | $0.416231 \times 10^{-6}$ | $0.416 \times 10^{-6}$ | meter to fourth power | m$^4$ |
| Moment of inertia (mass) | | | | | |
| slug foot squared | slug-ft$^2$ | 1.35582 | 1.36 | kilogram meter squared | kg·m$^2$ |
| Power | | | | | |
| foot-pound per second | ft-lb/s | 1.35582 | 1.36 | watt (J/s or N·m/s) | W |
| foot-pound per minute | ft-lb/min | 0.0225970 | 0.0226 | watt | W |
| horsepower (550 ft-lb/s) | hp | 745.701 | 746 | watt | W |
| Pressure; stress | | | | | |
| pound per square foot | psf | 47.8803 | 47.9 | pascal (N/m$^2$) | Pa |
| pound per square inch | psi | 6894.76 | 6890 | pascal | Pa |
| kip per square foot | ksf | 47.8803 | 47.9 | kilopascal | kPa |
| kip per square inch | ksi | 6.89476 | 6.89 | megapascal | MPa |
| Section modulus | | | | | |
| inch to third power | in.$^3$ | 16,387.1 | 16,400 | millimeter to third power | mm$^3$ |
| inch to third power | in.$^3$ | $16.3871 \times 10^{-6}$ | $16.4 \times 10^{-6}$ | meter to third power | m$^3$ |
| Velocity (linear) | | | | | |
| foot per second | ft/s | 0.3048* | 0.305 | meter per second | m/s |
| inch per second | in./s | 0.0254* | 0.0254 | meter per second | m/s |
| mile per hour | mph | 0.44704* | 0.447 | meter per second | m/s |
| mile per hour | mph | 1.609344* | 1.61 | kilometer per hour | km/h |
| Volume | | | | | |
| cubic foot | ft$^3$ | 0.0283168 | 0.0283 | cubic meter | m$^3$ |
| cubic inch | in.$^3$ | $16.3871 \times 10^{-6}$ | $16.4 \times 10^{-6}$ | cubic meter | m$^3$ |
| cubic inch | in.$^3$ | 16.3871 | 16.4 | cubic centimeter (cc) | cm$^3$ |
| gallon (231 in.$^3$) | gal. | 3.78541 | 3.79 | liter | L |
| gallon (231 in.$^3$) | gal. | 0.00378541 | 0.00379 | cubic meter | m$^3$ |

*An asterisk denotes an *exact* conversion factor

***Note:*** **To convert from SI units to USCS units, *divide* by the conversion factor**

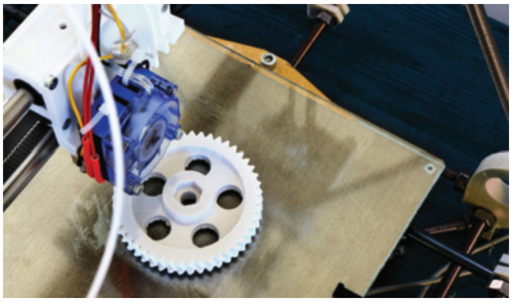
### Temperature Conversion Formulas

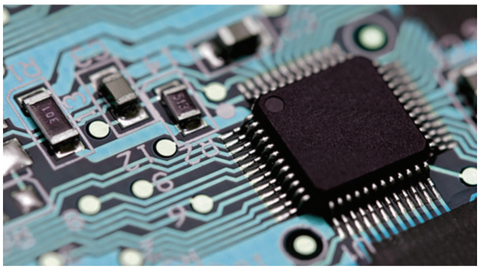
$$T(°C) = \frac{5}{9}[T(°F) - 32] = T(K) - 273.15$$

$$T(K) = \frac{5}{9}[T(°F) - 32] + 273.15 = T(°C) + 273.15$$

$$T(°F) = \frac{9}{5}T(°C) + 32 = \frac{9}{5}T(K) - 459.67$$

**Fifth Edition**





# Engineering Fundamentals, SI

## An Introduction to Engineering


**Saeed Moaveni**

**Minnesota State University, Mankato**

**SI edition prepared by: Keith McIver**



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**Saeed Moaveni**
**SI edition prepared by:**
**Keith McIver**

Product Director, Global Engineering: Timothy L. Anderson

Senior Content Developers: Hilda Gowans and Mona Zeftel

Media Assistant: Ashley Kaupert

Marketing Manager: Kristin Stine

Content Project Manager: D. Jean Buttrom

Director, Content and Media Production: Sharon L. Smith

Production Service: RPK Editorial Services, Inc.

Copyeditor: Shelly Gerger-Knechtl

Proofreader: Lori Martinsek

Indexer: RPK Editorial Services, Inc.

Compositor: Integra Software Services, Pvt. Ltd.

Senior Art Director: Michelle Kunkler

Cover and Internal Designer: c miller design

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Analyst: Christine Myaskovsky
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20 Channel Center Street
Boston, MA 02210
USA

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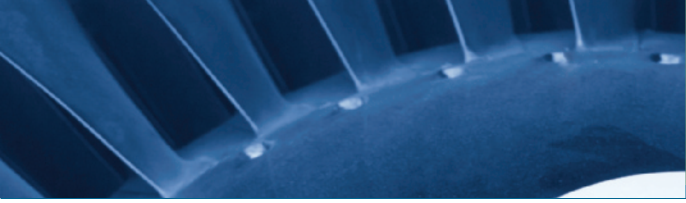
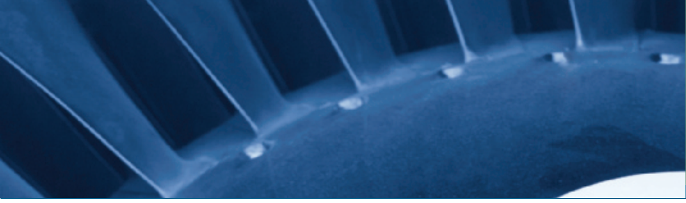


# Contents



# Preface

## Changes in the Fifth Edition

The Fifth Edition, consisting of twenty chapters, includes a number of new features, additions, and changes that were incorporated in response to pedagogical advances, suggestions, and requests made by professors and students using the Fourth Edition of the book. The major changes include:

### New Features

To promote active learning, we have added eight new features in the fifth edition of this book. These features include: (1) Learning Objectives (LO), (2) Discussion Starter—What Do You Think? (3) Before You Go On, (4) Highlighted Key Concepts, (5) Summary, (6) Key Terms, (7) Apply What You Have Learned, and (8) Life-long Learning Exercises.

1. **Learning Objectives (LO)**

   Each chapter begins by stating the learning objectives (LO).

2. **Discussion Starter**

   Pertinent articles serve as chapter openers to engage students and promote active learning. The discussion starters provide a current context for why the content that the students are about to learn is important. An instructor can start class by asking students to read the Discussion Starter and then ask the students for their thoughts and reactions.

3. **Before You Go On**

   This feature encourages students to test their comprehension and understanding of the material discussed in section(s) by answering questions, before they continue to the next section(s).

   **Vocabulary**—It is important for students to understand that they need to develop a comprehensive vocabulary to communicate effectively as well educated engineers and intelligent citizens. This feature promotes growing vocabulary by asking students to state the meaning of new words that are covered in section(s).

4. **Highlighted Key Concepts**

   Key concepts are highlighted in blue boxes and displayed throughout the book.

5. **Summary**

   Each chapter concludes by summarizing what the student should have gained from studying the chapter. Moreover, the learning objectives and the summary are tied together as a refresher for the students.

6. **Key Terms**

   The key terms are indexed at the end of each chapter so that students may return to them for review.

7. **Apply What You Have Learned**

   This feature encourages students to apply what they have learned to an interesting problem or a situation. To emphasize the importance of teamwork and to encourage group participation, many of these problems require group work.

8. Life-long Learning Exercises

   Problems that promote life-long learning are denoted by .

## MindTap

This textbook is also available as a course or supplement to the textbook through Cengage Learning's MindTap, a personalized learning program. Students who purchase the MindTap version have access to the book's MindTap Reader and are able to complete homework and assessment material online, through their desktop, laptop, or iPad. If you are using a Learning Management System (such as Blackboard or Moodle) for tracking course content, assignments, and grading, you can seamlessly access the MindTap suite of content and assessments for this course.

In MindTap, instructors can:

- Personalize the Learning Path to match the course syllabus by rearranging content or appending original material to the online content.
- Connect a Learning Management System portal to the online course and Reader
- Customize online assessments and assignments
- Track student progress and comprehension
- Promote student engagement through interactivity and exercises

Additionally, students can listen to the text through ReadSpeaker, take notes, create their own flashcards, highlight content for easy reference, and check their understanding of the material through practice quizzes and homework.

## Additional Content in the Fifth Edition

- A new section on Visual Basic for Applications (VBA). Excel's VBA is a programming language that allows students to use Excel more effectively and use the capabilities of VBA to solve a wide range of engineering problems. In Section 14.5, we explain how to input and retrieve data, display results, create a subroutine, and how to use Excel's Built-in functions in a VBA program. We also explain how to create a loop and the use of arrays. Students learn how to create a custom dialogue box.

- Over fifty new problems have been added throughout the book.

- Instructor resources include new Lecture Note PowerPoint slides and Test Banks for each chapter.

## Organization

This book is organized into six parts and twenty chapters. Each chapter begins by stating its objectives and concludes by summarizing what the student should have gained from studying that chapter. I have included enough material for two semester-long courses. The reason for this approach is to give the instructor sufficient materials and the flexibility to choose specific topics to meet his or her needs. Relevant, everyday examples with which students can easily associate are provided in every chapter. Each chapter includes many hands-on problems, requiring the student to gather and analyze information. Moreover, information collection and proper use of information are encouraged in this book by asking students to complete a number of assignments that require information gathering by using the Internet as well as employing traditional methods. Many of the problems require students to make brief reports so that they learn that successful engineers need to have good written and oral communication skills. To emphasize the importance of teamwork in engineering and to encourage group participation, many of the assignment problems require group work; some require the participation of the entire class.

The main parts of the book are:

## Part One: Engineering—An Exciting Profession

In Chapters 1 through 5, we introduce the students to the engineering profession, how to prepare for an exciting engineering career, the design process, engineering communication, and ethics. Chapter 1 provides a comprehensive introduction to the engineering profession and its branches. It explains some of the common traits of good engineers. Various engineering disciplines and engineering organizations are discussed. In Chapter 1, we also emphasize that engineers are problem solvers. Engineers have a good grasp of fundamental physical and chemical laws and mathematics, and apply these fundamental laws and principles to design, develop, test, and supervise the manufacture of millions of products and services. The examples, demonstrate the many satisfying and challenging jobs for engineers. We point out that although the activities of engineers can be quite varied, there are some personality traits and work habits that typify most of today's successful engineers:

- Engineers are problem solvers.
- Good engineers have a firm grasp of the fundamental principles that can be used to solve many different problems.
- Good engineers are analytical, detailed oriented, and creative.
- Good engineers have a desire to be life-long learners. For example, they take continuing education classes, seminars, and workshops to stay abreast of new innovations and technologies.
- Good engineers have written and oral communication skills that equip them to work well with their colleagues and to convey their expertise to a wide range of clients.
- Good engineers have time management skills that enable them to work productively and efficiently.
- Good engineers have good "people skills" that allow them to interact and communicate effectively with various people in their organization.
- Engineers are required to write reports. These reports might be lengthy, detailed, and technical, containing graphs, charts, and engineering drawings. Or they may take the form of a brief memorandum or an executive summary.
- Engineers are adept at using computers in many different ways to model and analyze various practical problems.
- Good engineers actively participate in local and national discipline-specific organizations by attending seminars, workshops, and meetings. Many even make presentations at professional meetings.
- Engineers generally work in a team environment where they consult each other to solve complex problems. Good interpersonal and communication skills have become increasingly important now because of the global market.

Chapter 1 explains the difference between an *engineer* and an *engineering technologist,* and the difference in their career options. In Chapter 2, the transition from high school to college is explained in terms of the need to form good study habits and suggestions are provided on how to budget time effectively. Chapter 3 provides an introduction to engineering design, sustainability, teamwork, and standards and codes. We show that engineers, regardless of their background, follow certain steps when designing products and services. Chapter 4 shows that presentations are an integral part of any engineering project. Depending on the size of the project, presentations might be brief, lengthy, frequent, and may follow a certain format requiring calculations, graphs, charts, and engineering drawings. In Chapter 4, various forms of engineering communication, including homework presentation, brief technical memos, progress reports, detailed technical reports, and research papers are explained. Chapter 5 emphasizes engineering ethics by noting that engineers design many products and provide many services that affect our quality of life and safety. Therefore, engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct. A large number of engineering ethics-related case studies are presented in this chapter.

## Part Two: Engineering Fundamentals—Concepts Every Engineer Should Know

Chapters 6 through 13 focus on engineering fundamentals and introduce students to the basic principles and physical laws that they will encounter repeatedly during the next four years. Successful engineers have a good grasp of the Fundamentals, which they can use to understand and solve many different problems. These are concepts that every engineer, regardless of his or her area of specialization, should know.

In these chapters, we emphasize that we need only a few physical quantities to fully describe events and our surroundings. These are length, time, mass, force, temperature, mole, and electric current. We also explain that we need not only physical dimensions to describe our surroundings, but also some way to scale or divide these physical dimensions. For example, time is considered a physical dimension, but it can be divided into both small and large portions, such as seconds, minutes, hours, days, years, decades, centuries, and millennia.

We discuss common systems of units and emphasize that engineers must know how to convert from one system of units to another and always show the appropriate units that go with their calculations. We also explain that the physical laws and formulas that engineers use are based on observations of their surroundings. We show that we use mathematics and basic physical quantities to express our observations.

In these chapters, we also explain that there are many engineering design variables that are related to the fundamental dimensions (quantities). To become a successful engineer a student must fully understand these fundamental and related variables and the pertaining governing laws and formulas. Then it is important for the student to know how these variables are measured, approximated, calculated, or used in practice.

Chapter 6 explains the role and importance of fundamental dimension and units in analysis of engineering problems. Basic steps in the analysis of any engineering problem are discussed in detail.

Chapter 7 introduces length and length-related variables and explains their importance in engineering work. For example, we discuss the role of area in heat transfer, aerodynamics, load distribution, and stress analysis. Measurement of length, area, and volume, along with numerical estimation (such as trapezoidal rule) of these values, are presented.

Chapter 8 considers time and time-related engineering variables. Periods, frequencies, linear and angular velocities and accelerations, volumetric flow rates and flow of traffic are also discussed in Chapter 8.

Chapter 9 covers mass and mass-related variables such as density, specific weight, mass flow rate, and mass moment of inertia, and their role in engineering analysis.

Chapter 10 discusses the importance of force and force-related variables in engineering. The important concepts in mechanics are explained conceptually. What is meant by force, internal force, reaction, pressure, modulus of elasticity, impulsive force (force acting over time), work (force acting over a distance) and moment (force acting at a distance) are covered in detail.

Chapter 11 presents temperature and temperature-related variables. Concepts such as temperature difference and heat transfer, specific heat, and thermal conductivity also are covered. As future engineers, it is important for students to understand some simple-energy-estimation procedures given current energy and sustainability concerns. Because of this fact, we have a section on Degree-Days and Energy Estimation.

Chapter 12 considers topics such as direct and alternating current, electricity, basic circuit components, power sources, and the tremendous role of electric motors in our everyday life. Lighting systems account for a major portion of electricity use in buildings and have received much attention lately. Section 12.4 introduces the basic terminology and concepts in lighting systems. All future engineers regardless of their area of expertise need to understand these basic concepts.

Chapter 13 presents energy and power and explains the distinction between these two topics. The importance of understanding what is meant by work, energy, power, watts, horsepower, and efficiency is emphasized. Energy sources, generation, and consumption in the United States are also discussed in this chapter. With the world's growing demand for energy being among the most difficult challenges that we face today, as future engineers, students need to understand two problems: energy sources and emission. Section 13.6 introduces conventional and renewable energy sources, generation, and consumption patterns.

## Part Three: Computational Engineering Tools—Using Available Software to Solve Engineering Problems

In Chapters 14 and 15, we introduce Microsoft Excel™ and MatLab™—two computational tools that are used commonly by engineers to solve engineering problems. These computational tools are used to record, organize, analyze data using formulas, and present the results of an analysis in chart forms. MatLab is also versatile enough that students can use it to write their own programs to solve complex problems.

## Part Four: Engineering Graphical Communication—Conveying Information to Other Engineers, Machinists, Technicians, and Managers

Chapter 16 introduces students to the principles and rules of engineering graphical communication and engineering symbols. A good grasp of these principles will enable students to convey and understand information effectively. We explain that engineers use technical drawings to convey useful information to others in a standard manner. An engineering drawing provides information, such as the shape of a product, its dimensions, materials from which to fabricate the product, and the assembly steps. Some engineering drawings are specific to a particular discipline. For example, civil engineers deal with land or boundary, topographic, construction, and route survey drawings. Electrical and electronic engineers, on the other hand, could deal with printed circuit board assembly drawings, printed circuit board drill plans, and wiring diagrams. We also show that engineers use special symbols and signs to convey their ideas, analyses, and solutions to problems.

## Part Five: Engineering Material Selection—An Important Design Decision

As engineers, whether you are designing a machine part, a toy, a frame of a car, or a structure, the selection of materials is an important design decision. Chapter 17 looks more closely at materials such as metals and their alloys, plastics, glass, wood, composites, and concrete that commonly are used in various engineering applications. We also discuss some of the basic characteristics of the materials that are considered in design.

## Part Six: Mathematics, Statistics, and Engineering Economics—Why Are They Important?

Chapters 18 through 20 introduce students to important mathematical, statistical, and economical concepts. We explain that engineering problems are mathematical models of physical situations. Some engineering problems lead to linear models, whereas others result in nonlinear models. Some engineering problems are formulated in the form of differential equations and some in the form of integrals. Therefore, a good understanding of mathematical concepts is essential in the formulation and solution of many engineering problems.

Moreover, statistical models are becoming common tools in the hands of practicing engineers to solve quality control and reliability issues, and to perform failure analyses. Civil engineers use statistical models to study the reliability of construction materials and structures, and to design for flood control, for example. Electrical engineers use statistical models for signal processing and for developing voice-recognition software. Manufacturing engineers use statistics for quality control assurance of the products they produce. Mechanical engineers use statistics to study the failure of materials and machine parts.

Economic factors also play important roles in engineering design decision making. If you design a product that is too expensive to manufacture, then it cannot be sold at a price that consumers can afford and still be profitable to your company.

## Case Studies—Engineering Marvels

To emphasize that engineers are problem solvers and that engineers apply physical and chemical laws and principles, along with mathematics, to *design* products and services that we use in our everyday lives, we include case studies throughout the book. Each case study is followed by assigned problems. The solutions to these problems incorporate the engineering concepts and laws that are discussed in the preceding chapters. There are also a number of engineering ethics case studies, from the National Society of Professional Engineers, in Chapter 5, to promote the discussion on engineering ethics.

## Impromptu Designs

I have included seven inexpensive impromptu designs that could be developed during class times. The basic ideas behind some of the impromptu designs have come from the ASME.

# References

In writing this book, several engineering books, Web pages, and other materials were consulted. Rather than giving you a list that contains hundreds of resources, I cite some of the sources that I believe to be useful to you. All freshmen engineering students should own a reference handbook in their chosen field. Currently, there are many engineering handbooks available in print or electronic format, including chemical engineering handbooks, civil engineering handbooks, electrical and electronic engineering handbooks, and mechanical engineering handbooks. I also believe all engineering students should own chemistry, physics, and mathematics handbooks. These texts can serve as supplementary resources for all your classes. Many engineers may find useful the ASHRAE handbook, the *Fundamental Volume,* by the American Society of Heating, Refrigerating, and Air Conditioning Engineers.

In this book, some data and diagrams were adapted with permission from the following sources:


- Baumeister, T., et al., *Mark's Handbook*, 8th ed., McGraw Hill, 1978.
- *Electrical Wiring*, 2nd ed., AA VIM, 1981.
- *Electric Motors*, 5th ed., AA VIM, 1982.
- Gere, J. M., *Mechanics of Materials*, 6th ed., Thomson, 2004.
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- Weston, K. C., *Energy Conversion*, West Publishing, 1992.

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Thank you for considering this book, and I hope you enjoy the Fifth Edition.

*Saeed Moaveni*

# Preface to the SI Edition

This edition of *ENGINEERING FUNDAMENTALS: AN INTRODUCTION TO ENGINEERING*, Fifth Edition has been adapted to incorporate the International System of Units (*Le Système International d'Unités* or SI) throughout the book.

## Le Système International d'Unités

The United States Customary System (USCS) of units uses FPS (foot–pound–second) units (also called English or Imperial units). SI units are primarily the units of the MKS (meter–kilogram–second) system. However, CGS (centimeter–gram–second) units are often accepted as SI units, especially in textbooks.

## Using SI Units in this Book

In this book, we have used both MKS and CGS units. USCS (U.S. Customary Units) or FPS (foot-pound-second) units used in the US Edition of the book have been converted to SI units throughout the text and problems. However, in case of data sourced from handbooks, government standards, and product manuals, it is not only extremely difficult to convert all values to SI, it also encroaches upon the intellectual property of the source. Some data in figures, tables, and references, therefore, remains in FPS units. For readers unfamiliar with the relationship between the USCS and the SI systems, a conversion table has been provided inside the front cover.

To solve problems that require the use of sourced data, the sourced values can be converted from FPS units to SI units just before they are to be used in a calculation. To obtain standardized quantities and manufacturers' data in SI units, the readers may contact the appropriate government agencies or authorities in their countries/regions.

## Instructor Resources

The Instructors' Solution Manual in SI units is available through your Sales Representative or online through the book website at http://login.cengage.com. A digital version of the ISM and PowerPoint slides of figures, tables, and examples from the SI text are available for instructors registering on the book website.

Feedback from users of this SI Edition will be greatly appreciated and will help us improve subsequent editions.

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# Engineering Fundamentals, SI

## An Introduction to Engineering

### Fifth Edition

PART 1

# Engineering

## An Exciting Profession

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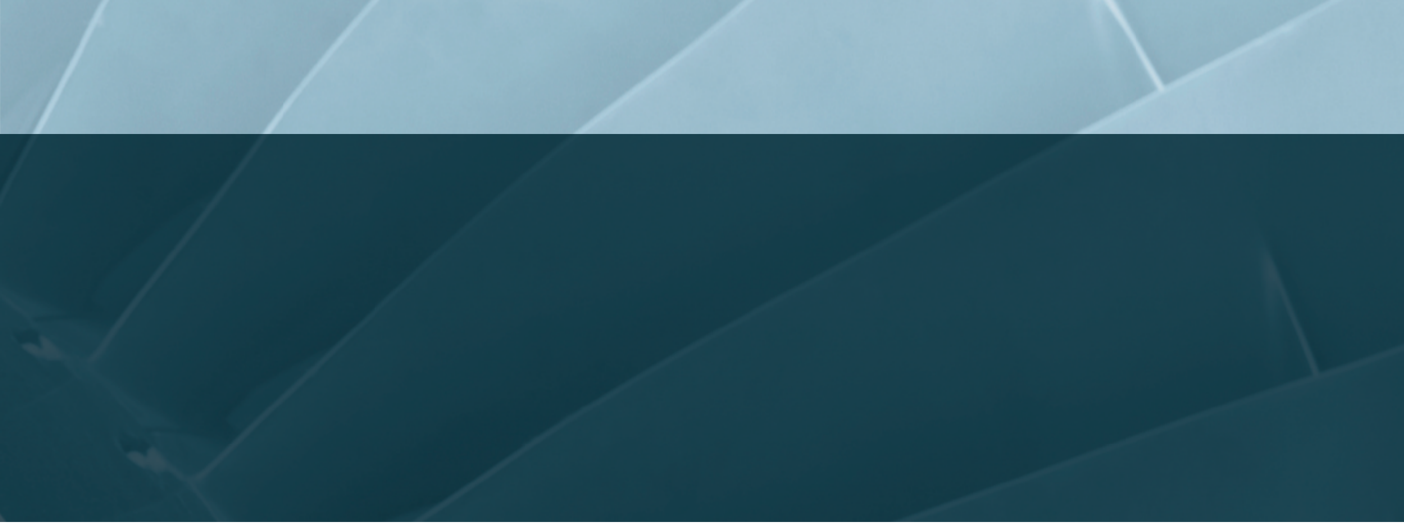

In Part One of this book, we will introduce you to the engineering profession. Engineers are problem solvers. They have a good grasp of fundamental physical and chemical laws and mathematics and apply these laws and principles to design, develop, test, and supervise the manufacture of millions of products and services. Engineers, regardless of their background, follow certain steps when designing the products and services we use in our everyday lives. Successful engineers possess good communication skills and are team players. Ethics plays a very important role in engineering. As eloquently stated by the National Society of Professional Engineers (NSPE) code of ethics, "Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior which requires adherence to the highest principles of ethical conduct." In the next five chapters, we will introduce you to the engineering profession, how to prepare for an exciting engineering career, the design process, engineering communication, and ethics.

> Good engineers are problem solvers and have a firm grasp of mathematical, physical, and chemical laws and principles. They apply these laws and principles to design products and services that we use in our everyday lives. They also have good written and oral communication skills.

CHAPTER 1

# Introduction to the Engineering Profession

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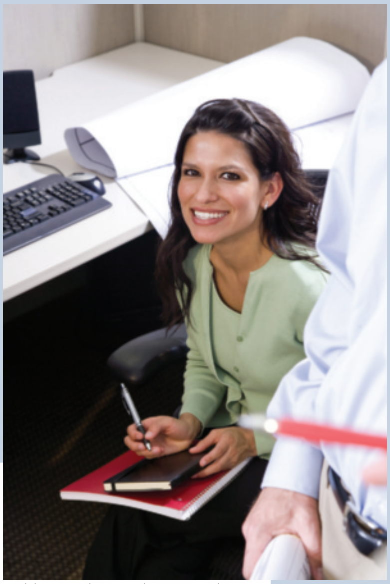

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NASA

Engineers are problem solvers. Successful engineers possess good communication skills and are team players. They have a good grasp of fundamental physical laws and mathematics. Engineers apply physical and chemical laws and mathematics to design, develop, test, and supervise the manufacture of millions of products and services. They consider important factors such as efficiency, cost, reliability, and safety when designing products. Good engineers are dedicated to lifelong learning and service to others.

## LEARNING OBJECTIVES

**LO1** **Engineering Work is All Around You:** give examples of products and services that engineers design that make our lives better

**LO2** **Engineering as a Profession:** describe what engineers do and give examples of common careers for engineers

**LO3** **Common Traits of Good Engineers:** describe the important traits of successful engineers

**LO4** **Engineering Disciplines:** give examples of common engineering disciplines and how they contribute to the comfort and betterment of our everyday lives

DISCUSSION STARTER

# WHO ARE ENGINEERS?

Engineers are problem solvers. They have a good grasp of fundamental physical and chemical laws and mathematics and apply these laws and principles to design, develop, test, and supervise the manufacture of millions of products and services. **Engineers**, regardless of their background, follow certain steps when designing the products and services we use in our everyday lives. Successful engineers possess good communication skills and are team players.

Ethics plays a very important role in engineering. As eloquently stated by the National Society of Professional Engineers (NSPE) code of ethics, "Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness and equity, and must be dedicated to the protection of the public health, safety and welfare. Engineers must perform under a standard of professional behavior which requires adherence to the highest principles of ethical conduct."


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**To the students:** What do you think engineers do? Why do you want to study engineering? Name at least two products or services that are not available now that you think will be readily available in the next 20 years. Which engineering disciplines do you think will be involved in design and development of these products and services?

Possibly some of you are not yet certain you want to study engineering during the next four years in college and may have questions similar to the following:

Do I really want to study engineering?
What is engineering and what do engineers do?
What are some of the areas of specialization in engineering?
How many different engineering disciplines are there?
Do I want to become a mechanical engineer, or should I pursue civil engineering? Or would I be happier becoming an electrical engineer?
How will I know that I have picked the best field for me?
Will the demand for my area of specialization be high when I graduate, and beyond that?

The main objectives of this chapter are to provide some answers to these and other questions you may have and to introduce you to the engineering profession and its various branches.

## LO[1] 1.1 Engineering Work Is All Around You

Engineers make products and provide services that make our lives better (see Figure 1.1). To see how engineers contribute to the comfort and the betterment of our everyday lives, tomorrow morning when you get up, just look around you more carefully. During the night, your bedroom was kept at the right temperature thanks to some mechanical engineers who designed the heating, air-conditioning, and ventilating systems in your home. When you get up in the morning and turn on the lights, be assured that thousands of mechanical and electrical engineers and technicians at power plants and power stations around the country are making certain the flow of electricity remains uninterrupted so that you have enough power to turn the lights on or turn on your TV to watch the morning news and weather report for the day. The TV you are using—to get your morning news or to see how your favorite team did—was designed by electrical and electronic engineers. There are, of course, engineers from other disciplines involved in creating the final product; for example, manufacturing and industrial engineers. When you are getting ready to take your morning shower, the clean water you are about to use is coming to your home thanks to civil and mechanical


**FIGURE 1.1** Examples of products and services designed by engineers.

engineers. Even if you live out in the country on a farm, the pump you use to bring water from the well to your home was designed by mechanical and civil engineers. The water could be heated by natural gas that is brought to your home thanks to the work and effort of chemical, mechanical, civil, and petroleum engineers. After your morning shower, when you get ready to dry yourself with a towel, think about what types of engineers worked behind the scenes to produce the towels. Yes, the cotton towel was made with the help of agricultural, industrial, manufacturing, chemical, petroleum, civil, and mechanical engineers. Think about the machines that were used to pick the cotton, transport the cotton to a factory, clean it, and dye it to a pretty color that is pleasing to your eyes. Then other machines were used to weave the fabric and send it to sewing machines that were designed by mechanical engineers. The same is true of the clothing you are about to wear. Your clothing may contain some polyester, which was made possible with the aid of petroleum and chemical engineers. “Well,” you may say, “I can at least sit down and eat my breakfast and not wonder whether some engineers made this possible as well.” But the food you are about to eat was made with the help and collaboration of various engineering disciplines, from agricultural to mechanical. Let’s say you are about to have some cereal. The milk was kept fresh in your refrigerator thanks to the efforts and work of mechanical engineers who designed the refrigerator components and chemical engineers who investigated alternative refrigerant fluids with appropriate thermal properties and other environmentally friendly properties that can be used in your refrigerator. Furthermore, electrical engineers designed the control and the electrical power units.

Now you are ready to get into your car or take the bus to go to school. The car you are about to drive was made possible with the help and collaboration of automotive, mechanical, electrical, electronic, industrial, material, chemical, and petroleum engineers. So, you see there is not much that you do in your daily life that has not involved the work of engineers. Be proud of the decision you have made to become an engineer. Soon you will become one of those whose behind-the-scenes efforts will be taken for granted by billions of people around the world. But you will accept that fact gladly, knowing that what you do will make people’s lives better.

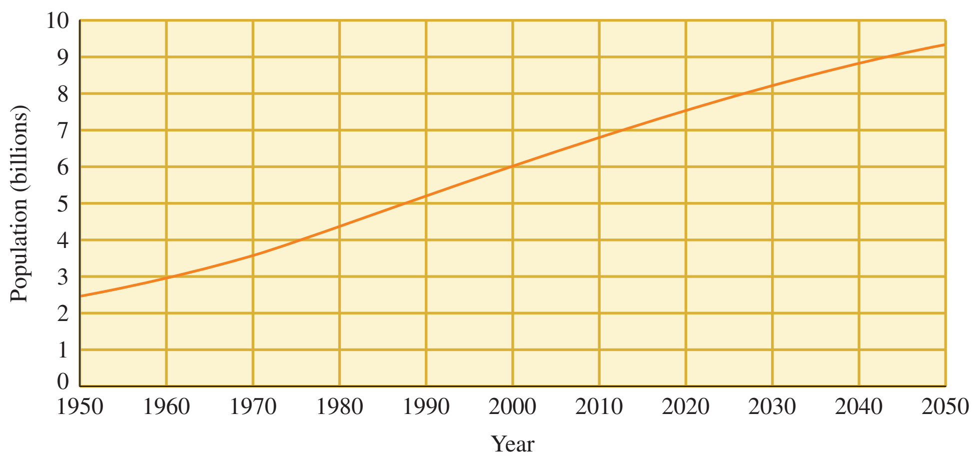
## Engineers Deal with an Increasing World Population and Sustainability Concerns

We as people, regardless of where we live, need the following things: food, clothing, shelter, clear air, and water. In addition, we need various modes of transportation to get to different places, because we may live and work in different cities or wish to visit friends and relatives who may live elsewhere. We also like to have some sense of security, to be able to relax and be entertained. We need to be liked and appreciated by our friends and family, as well.

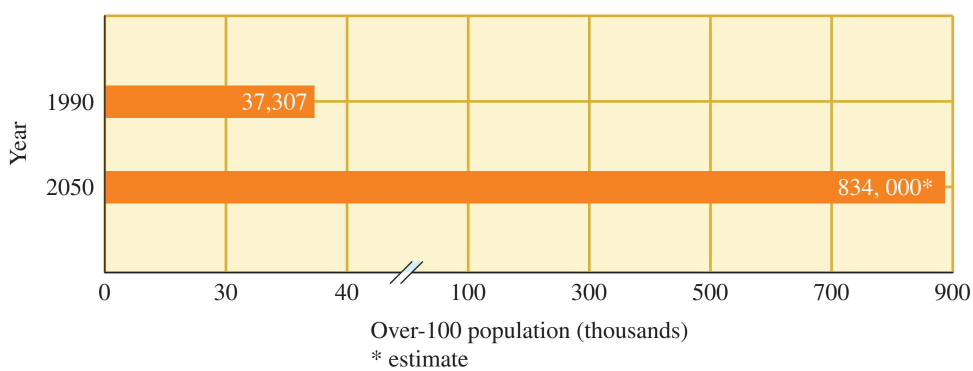
Increasingly, because of worldwide socioeconomic population trends, environmental concerns, and the earth’s finite resources, more is expected of engineers. Future engineers are expected to provide goods and services that increase the standard of living and advance health care while also addressing serious environmental and sustainability concerns. At the turn of the 21st century, there were approximately six billion of us inhabiting the earth. As a means of comparison, it is important to note that the world population about 115 years ago, at the start of the 20th century, was one billion. Think about it. It took us since the beginning of human existence to reach a population of one billion. It only took 115 years to increase the population by fivefold. Some of us have a good standard of living, but some of us living in developing countries do not. You will probably agree that our world would be a better place if every one of us had enough to eat, a comfortable and safe place to live, meaningful work to do, and some time for relaxation.

According to the latest estimates and projections of the U.S. Census Bureau, the world population will reach 9.3 billion people by the year 2050. Not only will the number of people inhabiting the earth continue to rise but the age structure of the world population will also change. The world's elderly population—the people at least 65 years of age—will more than double in the next 25 years (see Figure 1.2).

How is this information relevant? Well, now that you have decided to study to become an engineer, you need to realize that what you do in a few years after your graduation is very important to all of us. The world's




(a)




(b)

**FIGURE 1.2** (a) The latest projection of world population growth. (b) The latest estimate of U.S. elderly population growth.
Data from the U.S. Census Bureau

current economic development is not sustainable—the world population already uses approximately 20% more of the world's resources than the planet can sustain. (United Nations *Millenium Ecosystem Assessment Synthesis Report,* 2005.) You will design products and provide services especially suited to the needs and demands of an increasing elderly population as well as increased numbers of people of all ages. So prepare well to become a good engineer and be proud that you have chosen the engineering profession in order to contribute to raising the living standard for everyone and at the same time addressing environmental and sustainability concerns. Today's world economy is very dynamic. Corporations continually employ new technologies to maximize efficiency and profits. Because of this ongoing change and emerging technologies, new jobs are created and others are eliminated. Computers and smart electronic devices are continuously reshaping our way of life. Such devices influence the way we do things and help us provide the necessities of our lives—clean water, clean air, food, and shelter. You need to become a lifelong learner so that you can make informed decisions and anticipate as well as react to the global changes caused by technological innovations as well as population and environmental changes. According to the Bureau of Labor Statistics, U.S. Department of Labor, among the fastest-growing occupations are engineers, computer specialists, and systems analysts.

## LO2 1.2 Engineering as a Profession

In the following sections, we will first discuss **engineering** in a broad sense, and then we will focus on selected aspects of engineering. We will also look at the traits and characteristics common to many engineers. Next we will discuss some specific engineering disciplines. As we said earlier in this chapter, perhaps some of you have not yet decided what you want to study during your college years and consequently may have many questions, including: What is engineering and what do engineers do? What are some of the areas of specialization in engineering? Do I really want to study engineering? How will I know that I have picked the best field for me? Will the demand for my area of specialization be high when I graduate, and beyond that?

The following sections are intended to help you make a decision that you will be happy with; don't worry about finding answers to all these questions right now. You have some time to ponder them because most of the coursework during the first year of engineering is similar for all engineering students, regardless of their specific discipline. So you have at least a year to consider various possibilities. This is true at most educational institutions. Even so, you should talk to your advisor early to determine how soon you must choose an area of specialization. Don't be concerned about your chosen profession changing in a way that makes your education obsolete. Most companies assist their engineers in acquiring further training and education to keep up with changing technologies. A good engineering education will enable you to become a good problem solver throughout your life. You may wonder during the next few years of school why you need to be learning some of the material you are studying. Sometimes your homework may seem irrelevant, trivial, or out-of-date. Rest assured that you are learning both content information and strategies of thinking and analysis that will equip you to face future challenges, ones that do not even exist yet.