# PREFACE

## BACKGROUND

This text is an abbreviated version of standard thermodynamics and heat transfer texts, covering topics that the engineering students are most likely to need in their professional lives. The thermodynamics portion of this text is based on the text *Thermodynamics: An Engineering Approach* by Y. A. Çengel and M. A. Boles, and the heat transfer portion is based on *Heat and Mass Transfer: A Practical Approach* by Y. A. Çengel, both published by McGraw-Hill. Most chapters are practically independent of each other and can be covered in any order. The text is well-suited for curricula that have a common introductory course on thermodynamics and heat transfer. Instructors who desire to incorporate some coverage of fluid mechanics in their courses may wish to use the textbook *Fundamentals of Thermal-Fluid Sciences* instead, as it offers coverage of the essentials of fluid mechanics in addition to the thermodynamics and the heat transfer coverage in this book.

It is recognized that all topics of thermodynamics, and heat transfer cannot be covered adequately in a typical three-semester-hour course, and, therefore, sacrifices must be made from the depth if not from the breadth. Selecting the right topics and finding the proper level of depth and breadth are no small challenge for the instructors, and this text is intended to serve as the ground for such selection. Students in a combined thermal sciences course can gain a basic understanding of energy and energy interactions, as well as various mechanisms of heat transfer. Such a course can also instill in students the confidence and the background to do further reading of their own and to be able to communicate effectively with specialists in thermal sciences.

## OBJECTIVES

This book is intended for use as a textbook in a first course in thermal sciences for undergraduate engineering students in their junior or senior year, and as a reference book for practicing engineers. Students are assumed to have an adequate background in calculus, physics, and engineering mechanics. The objectives of this text are

- To cover the *basic principles* of thermodynamics and heat transfer.
- To present numerous and diverse real-world *engineering examples* to give students a feel for how thermal sciences are applied in engineering practice.
- To develop an *intuitive understanding* of thermal sciences by emphasizing the physics and physical arguments.

The text contains sufficient material to give instructors flexibility and to accommodate their preferences on the right blend of thermodynamics and heat transfer for their students. By careful selection of topics, an instructor can spend one-third, one-half, or two-thirds of the course on thermodynamics and the rest on selected topics of heat transfer.

## PHILOSOPHY AND GOAL

The philosophy that contributed to the warm reception of the first edition of this book has remained unchanged. Namely, our goal is to offer an engineering textbook that

- Communicates directly to the minds of tomorrow's engineers in a *simple yet precise* manner.
- Leads students towards a clear understanding and firm grasp of the *basic principles* of thermodynamics and heat transfer.
- Encourages *creative thinking* and development of a *deeper understanding* and *intuitive feel* for thermodynamics and heat transfer.
- Is *read* by students with *interest* and *enthusiasm* rather than being used as an aid to solve problems.

Special effort has been made to appeal to readers' natural curiosity and to help students explore the various facets of the exciting subject area of thermal sciences. The enthusiastic response we received from the users of the previous edition—from small colleges to large universities all over the world—indicates that our objectives have largely been achieved. It is our philosophy that the best way to learn is by practice. Therefore, special effort is made throughout the book to reinforce material that was presented earlier.

Yesterday's engineers spent a major portion of their time substituting values into the formulas and obtaining numerical results. However, now formula manipulations and number crunching are being left to computers. Tomorrow's engineer will need to have a clear understanding and a firm grasp of the *basic principles* so that he or she can understand even the most complex problems, formulate them, and interpret the results. A conscious effort is made to emphasize these basic principles while also providing students with a look at how modern tools are used in engineering practice.

## NEW IN THIS EDITION

All the popular features of the previous edition is retained while new ones are added. The main body of the text remains largely unchanged except that two new chapters are added, and two chapters are removed. The most significant changes in this edition are highlighted below.

### EARLY INTRODUCTION OF THE FIRST LAW OF THERMODYNAMICS

The first law of thermodynamics is now introduced early Chapter 3, "Energy, Energy Transfer, and General Energy Analysis." This introductory chapter sets the framework of establishing a general understanding of various forms of energy, mechanisms of energy transfer, the concept of energy balance, thermoeconomics, energy conversion, and conversion efficiency using familiar settings that involve mostly electrical and mechanical forms of energy. It also exposes students to some exciting real-world applications of thermodynamics early in the course, and helps them establish a sense of the monetary value of energy.

## COMPREHENSIVE PROBLEMS WITH EXTENSIVE PARAMETRIC STUDIES

A distinctive feature of this edition is the incorporation of numerous comprehensive problems that require conducting extensive parametric studies, using the enclosed EES (or other suitable) software. Students are asked to study the effects of certain variables in the problems on some quantities of interest, to plot the results, and to draw conclusions from the results obtained. These problems are designated by a square computer-EES icon for easy recognition, and can be ignored if desired. Solutions of these problems are given in the Instructor's Manual.

## EXPANDED COVERAGE OF CONVECTION

Forced convection is now covered in two chapters instead of one. Chapter 12 deals with the practical analysis of external convection while Chapter 13 deals with the practical aspects of internal convection.

## UPDATED STEAM AND REFRIGERANT-134A TABLES

The steam and refrigerant-134a tables are updated using the most current property data from EES. Tables A-4 through A-8, and A-11 through A-13, as well as their counterparts in English units have all been revised. All the examples and homework problems in the text that involve steam or refrigerant-134a are also revised to reflect the small changes in steam and refrigerant properties. An added advantage of this update is that students will get the same result when solving problems whether they use steam or refrigerant properties from EES or property tables in the Appendices.

## LEARNING OBJECTIVES

Each chapter now begins with an *overview* of the material to be covered and chapter-specific *learning objectives* to introduce the material and to set goals.

## CONTENT CHANGES AND REORGANIZATION

The noteworthy changes in various chapters are summarized below for those who are familiar with the previous edition.

- The text now starts with a new introductory chapter *Introduction and Overview* where thermodynamics and heat transfer are introduced, dimensions and units are discussed, and a systematic problem solving approach is described.
- The new Chapter 3 mainly consists of the sections *Forms of Energy*, *Energy and the Environment*, *Energy Transfer by Heat*, *Energy Transfer by Work*, *Mechanical Forms of Energy*, *The First Law of Thermodynamics*, and *Energy Conversion Efficiencies*.
- Chapters 3 and 4 (now Chapters 5 and 6) on the first law of thermodynamics for closed systems and control volumes remain largely unchanged, but a new intutive "energy balance" approach is used in problem solving. Also, coverage is extended to include unsteady flow *systems*.
- Chapter 6 (now Chapter 8) *Entropy* is revised considerably, and the section on *Entropy Balance* is moved to the end of the chapter.

- Chapter 7 *Power and Refrigeration Cycles* is deleted, but is available for downloading from the web site as a PDF file if needed.
- Chapter 8, *Steady Heat Conduction*, is now replaced by two chapters: Chapter 9 *Mechanisms of Heat Transfer*, where the three basic heat transfer mechanisms are introduced; and Chapter 10 *Steady Heat Conduction*, where steady conduction problems in various geometries are solved.
- Chapter 9 (now Chapter 11), *Transient Heat Conduction,* is greatly expanded to include the derivation of one-term solutions and additional cases of heat transfer in semi-infinite bodies.
- Chapter 10, *Forced Convection*, is now replaced by two chapters: Chapter 12 *External Forced Convection*, where the basic concepts of convection are introduced and drag and heat transfer for flow over surfaces, including flow over tube banks, are discussed; and Chapter 13 *Internal Forced Convection*, where pressure drop and heat transfer for flow in tubes are presented.
- Chapter 11 (now Chapter 14) *Natural Convection* is completely rewritten. The Grashof number is derived from a momentum balance on a differential volume element, some Nusselt number relations (especially those for rectangular enclosures) are updated, and the section *Natural Convection from Finned Surfaces* is expanded to include heat transfer from PCBs.
- In Chapter 12 (now Chapter 15) *Radiation Heat Transfer*, the sections on *Atmospheric and Solar Radiation* and *Radiation Shields* are deleted.
- In Appendices 1 and 2, the steam and refrigerant-134a tables (Tables 4 through 8 and 11 through 13) are entirely revised, but the table numbers are kept the same. Appendix 3 *Introduction to EES* is in the Student Resources DVD that comes packaged free with the text.
- The conversion factors on the inner cover pages and the physical constants are updated, and some nomenclature symbols are revised.

# LEARNING TOOLS

## EMPHASIS ON PHYSICS

A distinctive feature of this book is its emphasis on the physical aspects of subject matter in addition to mathematical representations and manipulations. The authors believe that the emphasis in undergraduate education should remain on *developing a sense of underlying physical mechanisms* and a *mastery of solving practical problems* that an engineer is likely to face in the real world. Developing an intuitive understanding should also make the course a more motivating and worthwhile experience for the students.

## EFFECTIVE USE OF ASSOCIATION

An observant mind should have no difficulty understanding engineering sciences. After all, the principles of engineering sciences are based on our *everyday experiences* and *experimental observations.* A more physical, intuitive approach is used throughout this text. Frequently, *parallels are drawn* between the subject matter and students' everyday experiences so that they can relate the subject matter to what they already know.

## SELF-INSTRUCTING

The material in the text is introduced at a level that an average student can follow comfortably. It speaks to students, not over students. In fact, it is *self-instructive.* Noting that the principles of science are based on experimental observations, most of the derivations in this text are largely based on physical arguments, and thus they are easy to follow and understand.

## EXTENSIVE USE OF ARTWORK

Figures are important learning tools that help the students "get the picture." The text makes effective use of graphics, and it contains a great number of figures and illustrations. Figures attract attention and stimulate curiosity and interest. Some of the figures in this text are intended to serve as a means of emphasizing some key concepts that would otherwise go unnoticed; some serve as page summaries.

## CHAPTER OPENERS AND SUMMARIES

Each chapter begins with an overview of the material to be covered and chapter objectives. A *summary* is included at the end of each chapter for a quick review of basic concepts and important relations.

## NUMEROUS WORKED-OUT EXAMPLES

Each chapter contains several worked-out *examples* that clarify the material and illustrate the use of the basic principles. An *intuitive* and *systematic* approach is used in the solution of the example problems, with particular attention to the proper use of units.

## A WEALTH OF REAL-WORLD END-OF-CHAPTER PROBLEMS

The end-of-chapter problems are grouped under specific topics in the order they are covered to make problem selection easier for both instructors and students. Within each group of problems are *Concept Questions*, indicated by "C" to check the students' level of understanding of basic concepts. The problems under *Review Problems* are more comprehensive in nature and are not directly tied to any specific section of a chapter—in some cases they require review of material learned in previous chapters. The problems under the *Design and Essay Problems* title are intended to encourage students to make engineering judgments, to conduct independent exploration of topics of interest, and to communicate their findings in a professional manner. Several economics- and safety-related problems are incorporated throughout to enhance cost and safety awareness among engineering students. Answers to selected problems are listed immediately following the problem for convenience to students.

## A SYSTEMATIC SOLUTION PROCEDURE

A well-structured approach is used in problem solving while maintaining an informal conversational style. The problem is first stated and the objectives are identified, and the assumptions made are stated together with their justifications. The properties needed to solve the problem are listed separately. Numerical values are used together with their units to emphasize that numbers without units are meaningless, and unit manipulations are as important as manipulating the numerical values with a calculator. The significance of the findings is discussed following the solutions. This approach is also used consistently in the solutions presented in the Instructor's Solutions Manual.

### RELAXED SIGN CONVENTION

The use of a formal sign convention for heat and work is abandoned as it often becomes counterproductive. A physically meaningful and engaging approach is adopted for interactions instead of a mechanical approach. Subscripts "in" and "out," rather than the plus and minus signs, are used to indicate the directions of interactions.

### A CHOICE OF SI ALONE OR SI / ENGLISH UNITS

In recognition of the fact that English units are still widely used in some industries, both SI and English units are used in this text, with an emphasis on SI. The material in this text can be covered using combined SI/English units or SI units alone, depending on the preference of the instructor. The property tables and charts in the appendices are presented in both units, except the ones that involve dimensionless quantities. Problems, tables, and charts in English units are designated by "E" after the number for easy recognition, and they can be ignored easily by the SI users.

### CONVERSION FACTORS

Frequently used conversion factors and physical constants are listed on the inner cover pages of the text for easy reference.

## SUPPLEMENTS

The following supplements are available to the adopters of the book.

### *ENGINEERING EQUATION SOLVER (EES) DVD*

(Limited Academic Version packaged free with every new copy of the text) Developed by Sanford Klein from the University of Wisconsin–Madison, this software combines equation-solving capability and engineering property data. EES can do optimization, parametric analysis, and linear and nonlinear regression, and provides publication-quality plotting capabilities. Thermodynamic and transport properties for air, water, and many other fluids are built in, and EES allows the user to enter property data or functional relationships. Some problems are solved using EES, and complete solutions together with parametric studies are included on the enclosed DVD.

### *TEXTBOOK WEBSITE (www.mhhe.com/cengel)*

Visit the text website for general text information, errata, and author information. The site also includes resources for students including a list of helpful web links. The instructor side of the site includes the solutions manual, the text's images in PowerPoint form, and more!

## ACKNOWLEDGMENTS

We would like to acknowledge with appreciation the numerous and valuable comments, suggestions, criticisms, and praise of these academic evaluators: Heather L. Cooper, Purdue University and Charles W. Knisely, Bucknell University.

Their suggestions have greatly helped to improve the quality of this text. Special thanks are due to Mehmet Kanoglu of the University of Gaziantep, Turkey, for his valuable contributions and his critical review of the manuscript and for his special attention to accuracy and detail. I also would like to thank our students who provided plenty of feedback from their perspectives. Finally, I would like to express my appreciation to my wife and children for their continued patience, understanding, and support throughout the preparation of this text.

**Yunus A. Çengel**