PREFACE

BACKGROUND

Heat and mass transfer is a basic science that deals with the rate of transfer of thermal energy. It has a broad application area ranging from biological systems to common household appliances, residential and commercial buildings, industrial processes, electronic devices, and food processing. Students are assumed to have an adequate background in calculus and physics. The completion of first courses in thermodynamics, fluid mechanics, and differential equations prior to taking heat transfer is desirable. However, relevant concepts from these topics are introduced and reviewed as needed.

OBJECTIVES

This book is intended for undergraduate engineering students in their sophomore or junior year, and as a reference book for practicing engineers. The objectives of this text are

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

It is our hope that this book, through its careful explanations of concepts and its use of numerous practical examples and figures, helps the students develop the necessary skills to bridge the gap between knowledge and the confidence for proper application of that knowledge.

In engineering practice, an understanding of the mechanisms of heat transfer is becoming increasingly important since heat transfer plays a crucial role in the design of vehicles, power plants, refrigerators, electronic devices, buildings, and bridges, among other things. Even a chef needs to have an intuitive understanding of the heat transfer mechanism in order to cook the food "right" by adjusting the rate of heat transfer. We may not be aware of it, but we already use the principles of heat transfer when seeking thermal comfort. We insulate our bodies by putting on heavy coats in winter, and we minimize heat gain by radiation by staying in shady places in summer. We speed up the cooling of hot food by blowing on it and keep warm in cold weather by cuddling up and thus minimizing the exposed surface area. That is, we already use heat transfer whether we realize it or not.

GENERAL APPROACH

This text is the outcome of an attempt to have a textbook for a practically oriented heat transfer course for engineering students. The text covers the standard topics of heat transfer with an emphasis on physics and real-world applications. This approach is more in line with students' intuition, and makes learning the subject matter enjoyable.

The philosophy that contributed to the overwhelming popularity of the prior editions of this book has remained unchanged in this edition. Namely, our goal has been to offer an engineering textbook that

- Communicates directly to the minds of tomorrow's engineers in a *simple yet precise* manner.
- Leads students toward a clear understanding and firm grasp of the *basic principles* of heat transfer.
- Encourages *creative thinking* and development of a *deeper understanding* and *intuitive feel* for 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 students' natural curiosity and to help them explore the various facets of the exciting subject area of heat transfer. The enthusiastic response we received from the users of prior editions—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 engineer spent a major portion of his or her time substituting values into the formulas and obtaining numerical results. However, now formula manipulations and number crunching are being left mainly to the computers. Tomorrow's engineer will have 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 perspective at how computational tools are used in engineering practice.

NEW IN THIS EDITION

Some of the primary changes in this fifth edition of the text include new and expanded coverage of heat transfer in biological systems, a new section on the general solutions to selected differential equations, and inclusion of example problems and end of chapter problems which incorporate the new Prevention through Design (PtD) concept. The concept of PtD involves proper use of design to promote safety and reduce accidents and injuries. We also have incorporated over 350 new problems. Each chapter, with the exception of Chapters 5 and 6, now contains one new solved example problem based on the concept of PtD, and a significant part of existing problems were modified. All the popular features of the previous editions are retained. The main body of all chapters, the organization of the text, and the tables and charts in the appendices remain mostly unchanged.

The fifth edition also includes **McGraw-Hill's Connect®** Engineering. This online homework management tool allows assignment of algorithmic problems for homework, quizzes and tests. It connects students with the tools and resources they'll need to achieve success. To learn more, visit www.mcgrawhillconnect.com

McGraw-Hill LearnSmart™ is also available as an integrated feature of McGraw-Hill Connect® Engineering. It is an adaptive learning system designed to help students learn faster, study more efficiently, and retain more knowledge for greater success. LearnSmart assesses a student's knowledge of course content through a series of adaptive questions. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. Visit the following site for a demonstration: www.mhlearnsmart.com

FUNDAMENTALS OF ENGINEERING (FE) EXAM PROBLEMS

To prepare students for the Fundamentals of Engineering Exam and to facilitate multiple-choice tests, over 200 *multiple-choice problems* are included in the end-of-chapter problem sets of this edition also. They are placed under the title "Fundamentals of Engineering (FE) Exam Problems" for easy recognition. These problems are intended to check the understanding of fundamentals and to help readers avoid common pitfalls. The EES solutions of these problems are available for instructors for ease of facilitation and easy modification.

PREVENTION THROUGH DESIGN (PtD) PROBLEMS

In 2007, the National Institute for Occupational Safety and Health launched the National Prevention through Design (PtD) initiative, with the mission to prevent or reduce work-related injuries, illnesses, and fatalities by including prevention considerations in all circumstances that impact individuals in the workplace. As such, the concept of PtD involves applying the means of reducing risks and preventing hazards in the design of equipment, tools, processes, and work facilities. The PtD concept is first introduced in Chapter 1. The idea of having example problems and end of chapter problems throughout the different chapters in the text is not only to simply provide discussions of interesting real world applications, but also to introduce the concepts of PtD to the minds of tomorrow's engineers whereby they may influence a change in culture toward more emphasis on safety designs.

NEW COVERAGE OF HEAT TRANSFER IN BIOLOGICAL SYSTEMS

Thermal Comfort is presented as a Topic of Special Interest in Chapter 1. This section is expanded and the term *thermoregulation* is introduced in this section. Thermoregulation means the body has mechanisms to act as a thermostat, when the core body temperature deviates from the normal resting value. Thermoregulation in the human body is achieved by keeping a tight balance between heat gain and heat loss. The "Bioheat Transfer Equation" introduced in Chapter 3 is used to calculate the heat transfer between a human body and its surroundings. Thermoregulation can be adjusted by both behavioral changes and physiological changes. Behavioral changes could be relocating to a more desirable environment within the structure or putting on more clothing. Physiological changes include blood vessel diameter changes and the production of sweat. However, under normal conditions, few of these changes

are needed because of the efficient organization of arteries and veins; they are arranged as a counter-current heat exchanger. This concept is presented in Chapter 11 as a Topic of Special Interest "The Human Cardiovascular System as a Counter-Current Heat Exchanger".

EXPANDED COVERAGE OF MINI AND MICRO TUBES

Owing to the rapid advancement in fabrication techniques, the use of the miniaturized devices and components is ever increasing. Whether it is in the application of miniature heat exchangers, fuel cells, pumps, compressors, turbines, sensors, or artificial blood vessels, a sound understanding of fluid flow in micro-scale channels and tubes is essential. Microscale Heat Transfer is presented as a Topic of Special Interest in Chapter 6. This edition expands the coverage of plain mini and micro tubes to spiral micro-fin tubes in Chapter 8.

THREE ONLINE APPLICATION CHAPTERS

The application chapters "Cooling of Electronic Equipment" (Chapter 15), "Heating and Cooling of Buildings" (Chapter 16), and "Refrigeration and Freezing of Foods" (Chapter 17) are available for download via the text website; go to www.mhhe.com/cengel for detailed coverage of these topics.

CONTENT CHANGES AND REORGANIZATION

With the exception of the changes already mentioned, minor changes are made in the main body of the text. Over 350 new problems are added, and a significant number of the existing problems are revised. The noteworthy changes in various chapters are summarized here for those who are familiar with the previous edition.

- In Chapter 1, the concept of Prevention through Design (PtD) has been introduced by Dr. Clement C. Tang of University of North Dakota. In addition, the coverage of Thermal Comfort presented as a Topic of Special Interest has been expanded by Dr. David A. Rubenstein of Stony Brook University.
- In Chapter 2, a new section "General Solution to Selected Differential Equations" is added.
- In Chapter 3, a new section "Bioheat Transfer Equation" is added.
- In Chapter 5, the section on "Interactive SS-T-CONDUCT Software" which introduced the software and demonstrated its use has been deleted and moved to text website. This information and the software are available from the online learning center (www.mhhe.com/cengel) to the instructors and students. The software can be used to solve or to check the solutions of many of the one- and two-dimensional heat conduction problems with uniform energy generation in rectangular geometries.
- In Chapter 8, a new subsection "Fully Developed Transitional Flow Heat Transfer" is added. Also, the coverage of subsections on "Pressure Drop in the Transition Region" and "Heat Transfer in the Transition Region" of the Topic of Special Interest on Transitional Flow in Tubes has been expanded.
- In Chapter 10, the coverage of the Topic of Special Interest on "Non-Boiling Two-Phase Flow Heat Transfer" has been expanded and a new

subsection on "Application of Reynolds Analogy to Non-Boiling Two-Phase Flow" has been added.

- In Chapter 11, the coverage of Heat Exchangers has been expanded and this chapter now has the Topic of Special Interest "The Human Cardiovascular System as a Counter-Current Heat Exchanger" contributed by Dr. David A. Rubenstein of Stony Brook University.
- In Chapter 14, the section on Water Vapor Migration in Buildings has been expanded.

LEARNING TOOLS

EMPHASIS ON PHYSICS

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.

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*. The process of cooking, for example, serves as an excellent vehicle to demonstrate the basic principles of heat transfer.

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*. The order of coverage is from *simple* to *general*.

EXTENSIVE USE OF ARTWORK

Art is an important learning tool that helps students "get the picture." The fifth edition of *Heat and Mass Transfer: Fundamentals & Applications* contains more figures and illustrations than any other book in this category.

LEARNING OBJECTIVES AND SUMMARIES

Each chapter begins with an *Overview* of the material to be covered and chapter-specific *Learning Objectives*. A *Summary* is included at the end of each chapter, providing a quick review of basic concepts and important relations, and pointing out the relevance of the material.

NUMEROUS WORKED-OUT EXAMPLES WITH A SYSTEMATIC SOLUTIONS PROCEDURE

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, while maintaining an informal conversational style. The problem is first stated, and the objectives are identified. The assumptions are then stated, together with their justifications. The properties needed to solve the problem are listed separately,

if appropriate. This approach is also used consistently in the solutions presented in the instructor's solutions manual.

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

The end-of-chapter problems are grouped under specific topics 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.
- ***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.
- ***Fundamentals of Engineering (FE) Exam Problems*** are designed to help students prepare for the *Fundamentals of Engineering* exam, as they prepare for their Professional Engineering license.

These problems are "Prevention through Design" related problems.

These problems are solved using EES, and complete solutions together with parametric studies are included on the textbook's website.

These problems are comprehensive in nature and are intended to be solved with a computer, possibly using the EES software.

- ***Design and Essay*** 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 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 by SI users.

TOPICS OF SPECIAL INTEREST

Most chapters contain a real world application, end-of-chapter optional section called "Topic of Special Interest" where interesting applications of heat transfer are discussed such as *Thermal Comfort* in Chapter 1, *Heat Transfer through the Walls and Roofs* in Chapter 3, *Microscale Heat Transfer* in Chapter 6, *Transitional Flow in Tubes* in Chapter 8, *Heat Transfer through Windows* in

Chapter 9, *Non-Boiling Two-Phase Flow Heat Transfer* in Chapter 10, *Human Cardiovascular System as a Counter-Current Heat Exchanger* in Chapter 11, and *Heat Transfer from the Human Body* in Chapter 13.

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 users of the book.

ENGINEERING EQUATION SOLVER (EES)

Developed by Sanford Klein and William Beckman 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. Thermodynamics 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.

EES is a powerful equation solver with built-in functions and property tables for thermodynamic and transport properties as well as automatic unit checking capability. It requires less time than a calculator for data entry and allows more time for thinking critically about modeling and solving engineering problems. Look for the EES icons in the homework problems sections of the text.

The Limited Academic Version of EES is available for departmental license upon adoption of the Fifth Edition of Heat and Mass Transfer: Fundamentals and Applications (meaning that the text is required for students in the course). You may load this software onto your institution's computer system, for use by students and faculty related to the course, as long as the arrangement between McGraw-Hill Education and F-Chart is in effect. There are minimum order requirements stipulated by F-Chart to qualify.

TEXT WEBSITE

Web support is provided for the text on the text specific website at www. mhhe.com/cengel

Visit this 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!

COSMOS

(Available to Instructors Only)

McGraw-Hill's COSMOS (Complete Online Solutions Manual Organization System) allows instructors to streamline the creation of assignments, quizzes, and texts by using problems and solutions from the textbook, as well as their own custom material. COSMOS is now available online at http://cosmos.mhhe.com

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Yunus A. Çengel
Afshin J. Ghajar