Preface

In the Preface to the previous edition, we posed questions regarding trends in engineering education and practice, and whether the discipline of heat transfer would remain relevant. After weighing various arguments, we concluded that the future of engineering was bright and that heat transfer would remain a vital and enabling discipline across a range of emerging technologies including but not limited to information technology, biotechnology, pharmacology, and alternative energy generation.

Since we drew these conclusions, many changes have occurred in both engineering education and engineering practice. Driving factors have been a contracting global economy, coupled with technological and environmental challenges associated with energy production and energy conversion. The impact of a weak global economy on higher education has been sobering. Colleges and universities around the world are being forced to set priorities and answer tough questions as to which educational programs are crucial, and which are not. *Was our previous assessment of the future of engineering, including the relevance of heat transfer, too optimistic?*

Faced with economic realities, many colleges and universities have set clear priorities. In recognition of its value and relevance to society, investment in engineering education has, in many cases, *increased.* Pedagogically, there is renewed emphasis on the fundamental principles that are the foundation for *lifelong learning*. The important and sometimes dominant role of heat transfer in many applications, particularly in conventional as well as in alternative energy generation and concomitant environmental effects, has reaffirmed its relevance. We believe our previous conclusions were correct: The future of engineering is bright, and heat transfer is a topic that is crucial to address a broad array of technological and environmental challenges.

In preparing this edition, we have sought to incorporate recent heat transfer research at a level that is appropriate for an undergraduate student. We have strived to include new examples and problems that motivate students with interesting applications, but whose solutions are based firmly on fundamental principles. We have remained true to the pedagogical approach of previous editions by retaining a rigorous and systematic methodology for problem solving. We have attempted to continue the tradition of providing a text that will serve as a valuable, everyday resource for students and practicing engineers throughout their careers.

Approach and Organization

Previous editions of the text have adhered to four learning objectives:

1. The student should internalize the meaning of the terminology and physical principles associated with heat transfer.
2. The student should be able to delineate pertinent transport phenomena for any process or system involving heat transfer.
3. The student should be able to use requisite inputs for computing heat transfer rates and/or material temperatures.
4. The student should be able to develop representative models of real processes and systems and draw conclusions concerning process/system design or performance from the attendant analysis.

Moreover, as in previous editions, specific learning objectives for each chapter are clarified, as are means by which achievement of the objectives may be assessed. The summary of each chapter highlights key terminology and concepts developed in the chapter and poses questions designed to test and enhance student comprehension.

It is recommended that problems involving complex models and/or exploratory, what-if, and parameter sensitivity considerations be addressed using a computational equation-solving package. To this end, the *Interactive Heat Transfer* (*IHT*) package available in previous editions has been updated. Specifically, a simplified user interface now delineates between the basic and advanced features of the software. It has been our experience that most students and instructors will use primarily the basic features of *IHT*. By clearly identifying which features are advanced, we believe students will be motivated to use *IHT* on a daily basis. A second software package, *Finite Element Heat Transfer* (FEHT), developed by F-Chart Software (Madison, Wisconsin), provides enhanced capabilities for solving two-dimensional conduction heat transfer problems.

To encourage use of *IHT*, a *Quickstart User's Guide* has been installed in the software. Students and instructors can become familiar with the basic features of *IHT* in approximately one hour. It has been our experience that once students have read the Quickstart guide, they will use *IHT* heavily, even in courses other than heat transfer. Students report that *IHT* significantly reduces the time spent on the mechanics of lengthy problem solutions, reduces errors, and allows more attention to be paid to substantive aspects of the solution. Graphical output can be generated for homework solutions, reports, and papers.

As in previous editions, some homework problems require a computer-based solution. Other problems include both a hand calculation and an extension that is computer based. The latter approach is time-tested and promotes the habit of checking a computer-generated solution with a hand calculation. Once validated in this manner, the computer solution can be utilized to conduct parametric calculations. Problems involving both hand- and computer-generated solutions are identified by enclosing the exploratory part in a red rectangle, as, for example, (b), (c), or (d). This feature also allows instructors who wish to limit their assignments of computer-based problems to benefit from the richness of these problems without assigning their computer-based parts. Solutions to problems for which the number is highlighted (for example, 1.26) are entirely computer based.

What's New in the 7th Edition

Chapter-by-Chapter Content Changes In the previous edition, *Chapter 1 Introduction* was modified to emphasize the relevance of heat transfer in various contemporary applications. Responding to today's challenges involving energy production and its environmental impact, an expanded discussion of the efficiency of energy conversion and the production of greenhouse gases has been added. Chapter 1 has also been modified to embellish the complementary nature of heat transfer and thermodynamics. The existing treatment of the first law of thermodynamics is augmented with a new section on the relationship between heat transfer and the second law of thermodynamics as well as the efficiency of heat engines. Indeed, the influence of heat transfer on the efficiency of energy conversion is a recurring theme throughout this edition.

The coverage of micro- and nanoscale effects in *Chapter 2 Introduction to Conduction* has been updated, reflecting recent advances. For example, the description of the thermophysical properties of composite materials is enhanced, with a new discussion of nanofluids. *Chapter 3 One-Dimensional, Steady-State Conduction* has undergone extensive revision and includes new material on conduction in porous media, thermoelectric power generation, and micro- as well as nanoscale systems. Inclusion of these new topics follows recent fundamental discoveries and is presented through the use of the thermal resistance network concept. Hence the power and utility of the resistance network approach is further emphasized in this edition.

Chapter 4 Two-Dimensional, Steady-State Conduction has been reduced in length. Today, systems of linear, algebraic equations are readily solved using standard computer software or even handheld calculators. Hence the focus of the shortened chapter is on the application of heat transfer principles to derive the systems of algebraic equations to be solved and on the discussion and interpretation of results. The discussion of Gauss–Seidel iteration has been moved to an appendix for instructors wishing to cover that material.

Chapter 5 Transient Conduction was substantially modified in the previous edition and has been augmented in this edition with a streamlined presentation of the lumped-capacitance method.

Chapter 6 Introduction to Convection includes clarification of how temperature-dependent properties should be evaluated when calculating the convection heat transfer coefficient. The fundamental aspects of compressible flow are introduced to provide the reader with guidelines regarding the limits of applicability of the treatment of convection in the text.

Chapter 7 External Flow has been updated and reduced in length. Specifically, presentation of the similarity solution for flow over a flat plate has been simplified. New results for flow over noncircular cylinders have been added, replacing the correlations of previous editions. The discussion of flow across banks of tubes has been shortened, eliminating redundancy without sacrificing content.

Chapter 8 Internal Flow entry length correlations have been updated, and the discussion of micro- and nanoscale convection has been modified and linked to the content of Chapter 3.

Changes to *Chapter 9 Free Convection* include a new correlation for free convection from flat plates, replacing a correlation from previous editions. The discussion of boundary layer effects has been modified.

Aspects of condensation included in *Chapter 10 Boiling and Condensation* have been updated to incorporate recent advances in, for example, external condensation on finned tubes. The effects of surface tension and the presence of noncondensable gases in modifying condensation phenomena and heat transfer rates are elucidated. The coverage of forced convection condensation and related enhancement techniques has been expanded, again reflecting advances reported in the recent literature.

The content of *Chapter 11 Heat Exchangers* is experiencing a resurgence in interest due to the critical role such devices play in conventional and alternative energy generation technologies. A new section illustrates the applicability of heat exchanger analysis to heat sink design and materials processing. Much of the coverage of compact heat exchangers included in the previous edition was limited to a specific heat exchanger. Although general coverage of compact heat exchangers has been retained, the discussion that is limited to the specific heat exchanger has been relegated to supplemental material, where it is available to instructors who wish to cover this topic in greater depth.

The concepts of emissive power, irradiation, radiosity, and net radiative flux are now introduced early in *Chapter 12 Radiation: Processes and Properties,* allowing early assignment of end-of-chapter problems dealing with surface energy balances and properties, as well as radiation detection. The coverage of environmental radiation has undergone substantial revision, with the inclusion of separate discussions of solar radiation, the atmospheric radiation balance, and terrestrial solar irradiation. Concern for the potential impact of anthropogenic activity on the temperature of the earth is addressed and related to the concepts of the chapter.

Much of the modification to *Chapter 13 Radiation Exchange Between Surfaces* emphasizes the difference between geometrical surfaces and radiative surfaces, a key concept that is often difficult for students to appreciate. Increased coverage of radiation exchange between multiple blackbody surfaces, included in older editions of the text, has been returned to Chapter 13. In doing so, radiation exchange between differentially small surfaces is briefly introduced and used to illustrate the limitations of the analysis techniques included in Chapter 13.

Chapter 14 Diffusion Mass Transfer was revised extensively for the previous edition, and only modest changes have been made in this edition.

Problem Sets Approximately 250 new end-of-chapter problems have been developed for this edition. An effort has been made to include new problems that (*a*) are amenable to short solutions or (*b*) involve finite-difference solutions. A significant number of solutions to existing end-of-chapter problems have been modified due to the inclusion of the new convection correlations in this edition.

Classroom Coverage

The content of the text has evolved over many years in response to a variety of factors. Some factors are obvious, such as the development of powerful, yet inexpensive calculators and software. There is also the need to be sensitive to the diversity of users of the text, both in terms of (*a*) the broad background and research interests of instructors and (*b*) the wide range of missions associated with the departments and institutions at which the text is used. Regardless of these and other factors, it is important that the four previously identified learning objectives be achieved.

Mindful of the broad diversity of users, the authors' intent is *not* to assemble a text whose content is to be covered, in entirety, during a single semester- or quarter-long course. Rather, the text includes both (*a*) fundamental material that we believe must be covered and (*b*) optional material that instructors can use to address specific interests or that can be covered in a second, intermediate heat transfer course. To assist instructors in preparing a syllabus for a *first course in heat transfer*, we have several recommendations.

Chapter 1 Introduction sets the stage for any course in heat transfer. It explains the linkage between heat transfer and thermodynamics, and it reveals the relevance and richness of the subject. It should be covered in its entirety. Much of the content of *Chapter 2 Introduction to Conduction* is critical in a first course, especially Section 2.1 The Conduction Rate Equation, Section 2.3 The Heat Diffusion Equation, and Section 2.4 Boundary and Initial Conditions. It is recommended that Chapter 2 be covered in its entirety.

Chapter 3 One-Dimensional, Steady-State Conduction includes a substantial amount of optional material from which instructors can *pick-and-choose* or defer to a subsequent, intermediate heat transfer course. The optional material includes Section 3.1.5 Porous Media, Section 3.7 The Bioheat Equation, Section 3.8 Thermoelectric Power Generation, and Section 3.9 Micro- and Nanoscale Conduction. Because the content of these sections is not interlinked, instructors may elect to cover any or all of the optional material.

The content of *Chapter 4 Two-Dimensional, Steady-State Conduction* is important because both (*a*) fundamental concepts and (*b*) powerful and practical solution techniques are presented. We recommend that all of Chapter 4 be covered in any introductory heat transfer course.

The optional material in *Chapter 5 Transient Conduction* is Section 5.9 Periodic Heating. Also, some instructors do not feel compelled to cover Section 5.10 Finite-Difference Methods in an introductory course, especially if time is short.

The content of *Chapter 6 Introduction to Convection* is often difficult for students to absorb. However, Chapter 6 introduces fundamental concepts and lays the foundation for the subsequent convection chapters. It is recommended that all of Chapter 6 be covered in an introductory course.

Chapter 7 External Flow introduces several important concepts and presents convection correlations that students will utilize throughout the remainder of the text and in subsequent professional practice. Sections 7.1 through 7.5 should be included in any first course in heat transfer. However, the content of Section 7.6 Flow Across Banks of Tubes, Section 7.7 Impinging Jets, and Section 7.8 Packed Beds is optional. Since the content of these sections is not interlinked, instructors may select from any of the optional topics.

Likewise, *Chapter 8 Internal Flow* includes matter that is used throughout the remainder of the text and by practicing engineers. However, Section 8.7 Heat Transfer Enhancement, and Section 8.8 Flow in Small Channels may be viewed as optional.

Buoyancy-induced flow and heat transfer is covered in *Chapter 9 Free Convection.* Because free convection thermal resistances are typically large, they are often the dominant resistance in many thermal systems and govern overall heat transfer rates. Therefore, most of Chapter 9 should be covered in a first course in heat transfer. Optional material includes Section 9.7 Free Convection Within Parallel Plate Channels and Section 9.9 Combined Free and Forced Convection. In contrast to resistances associated with free convection, thermal resistances corresponding to liquid-vapor phase change are typically small, and they can sometimes be neglected. Nonetheless, the content of *Chapter 10 Boiling and Condensation* that should be covered in a first heat transfer course includes Sections 10.1 through 10.4, Sections 10.6 through 10.8, and Section 10.11. Section 10.5 Forced Convection Boiling may be material appropriate for an intermediate heat transfer course. Similarly, Section 10.9 Film Condensation on Radial Systems and Section 10.10 Condensation in Horizontal Tubes may be either covered as time permits or included in a subsequent heat transfer course.

We recommend that all of *Chapter 11 Heat Exchangers* be covered in a first heat transfer course.

A distinguishing feature of the text, from its inception, is the in-depth coverage of radiation heat transfer in *Chapter 12 Radiation: Processes and Properties*. The content of the chapter is perhaps more relevant today than ever, with applications ranging from advanced manufacturing, to radiation detection and monitoring, to environmental issues related to global climate change. Although Chapter 12 has been reorganized to accommodate instructors who may wish to skip ahead to Chapter 13 after Section 12.4, we encourage instructors to cover Chapter 12 in its entirety.

Chapter 13 Radiation Exchange Between Surfaces may be covered as time permits or in an intermediate heat transfer course.

The material in *Chapter 14 Diffusion Mass Transfer* is relevant to many contemporary technologies, particularly those involving materials synthesis, chemical processing, and energy conversion. Emerging applications in biotechnology also exhibit strong diffusion mass transfer effects. Time permitting, we encourage coverage of Chapter 14. However, if only problems involving *stationary media* are of interest, Section 14.2 may be omitted or included in a follow-on course.

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Supplemental and Web Site Material

The companion web site for the texts is www.wiley.com/college/bergman. By selecting one of the two texts and clicking on the "student companion site" link, students may access the **Answers to Selected Exercises** and the **Supplemental Sections** of the text. Supplemental Sections are identified throughout the text with the icon shown in the margin to the left.

Material available *for instructors only* may also be found by selecting one of the two texts at www.wiley.com/college/bergman and clicking on the "instructor companion site" link. The available content includes the **Solutions Manual**, **PowerPoint Slides** that can be used by instructors for lectures, and **Electronic Versions** of figures from the text for those wishing to prepare their own materials for electronic classroom presentation. *The* Instructor Solutions Manual *is copyrighted material for use only by instructors who are requiring the text for their course.*[1]

Interactive Heat Transfer 4.0/FEHT is available either with the text or as a separate purchase. As described by the authors in the *Approach and Organization*, this simple-to-use software tool provides modeling and computational features useful in solving many problems in the text, and it enables rapid what-if and exploratory analysis of many types of problems. Instructors interested in using this tool in their course can download the software from the book's web site at www.wiley.com/college/bergman. Students can download the software by registering on the student companion site; for details, see the registration card provided in this book. The software is also available as a stand-alone purchase at the web site. Any questions can be directed to your local Wiley representative.

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