PREFACE TO THE THIRD EDITION

Another ten years have passed since the second edition of "Radiative Heat Transfer" was published. Thermal radiation remains a relatively young field, with basic relations dating back to the early 20th century, and serious heat transfer models only starting to appear in the 1950s. Consequently, continued interest in the field has led to many significant advances and the emergence of new research topics during these past ten years. Therefore, the contents of the third edition of this book has again changed significantly to reflect this additional knowledge, and further attempts have been made to improve its general readability and usefulness.

The objectives of this book remain the same, and are more extensive than to provide a standard textbook for a one-semester core course on thermal radiation, since it does not appear possible to cover all important topics in the field of radiative heat transfer in a single graduate course. A number of important areas that would not be part of a "standard" one-semester course have been treated in some detail. It is anticipated that the engineer who may have used this book as his or her graduate textbook will be able to master these advanced topics through self-study. By including all important advanced topics, as well as a large number of references for further reading, the book is also intended as a reference book for the practicing engineer.

Major changes in the third edition include breaking the chapter on the statistical Monte Carlo method into two. The first deals with surface radiation and is now placed much earlier in the book, giving instructors the opportunity to include it as part of the surface radiation discussion in a single semester course. The second, dealing with participating media, has been greatly augmented, incorporating the many new developments in the field, such as spectrally-resolved schemes, extensions for stochastic media, and others. The fields of inverse radiation and radiative transfer at the micro- and nanoscales have seen particularly much activity during the last 10 years. Therefore, the chapter on inverse radiation has been entirely rewritten, and a new chapter on nanoscale radiative heat transfer has been added. These two chapters should be understood as introductions to these extensive fields, giving the engineer a basic understanding of these new research areas, and a good foundation to embark on further reading of the pertinent literature. The chapters on gas properties and on nongray modeling have again seen very significant changes and additions because of the continued advances made in these fields and because of the growing interest in nonequilibrium radiation. The last ten years have also seen some further development in modern radiative transfer equation solution methods, reflected in the chapters on the spherical harmonics and discrete ordinates methods, in addition to the Monte Carlo method.

The appendix describing a number of computer programs has been retained, and the codes may be downloaded from a dedicated web site located at http://booksite.elsevier.com/9780123869449. Some of the codes are very basic and are entirely intended to aid the reader with the solution to the problems given at the end of the early chapters on surface transport. Others were born out of research, some basic enough to aid a graduate student with more complicated assignments or a semester project, and a few so sophisticated in nature that they will be useful only to the practicing engineer conducting his or her own research. Recognizing that many graduate students no longer learn compiler languages, such as Fortran and C++, the more basic programs are now also available in MATLAB®.

Many smaller changes have also been made, such as omission of some obsolete material, inclusion of many new small developments, and restructuring of material between chapters to aid readability. And, of course, a comprehensive literature update has been provided, and many new homework problems have been added at the end of the chapters.

As in the first two editions, each chapter shows the development of all analytical methods in substantial detail, and contains a number of examples to show how the developed relations may be applied to practical problems. At the end of each chapter a number of exercises are included to give the student additional opportunity to familiarize him- or herself with the application of analytical methods developed in the preceding sections. The breadth of the description of analytical developments is such that any scientist with a satisfactory background in calculus and differential equations will be able to grasp the subject through self-study—for example, the heat transfer engineer involved in furnace calculations, the architectural engineer interested in lighting calculations, the oceanographer concerned with solar penetration into the ocean, or the meteorologist who studies atmospheric radiation problems. An expanded Instructor's Solutions Manual is available for adopting instructors who register at http://textbooks.elsevier.com/web/product_details.aspx?isbn=9780123869449.

The book is now divided into 24 chapters, covering the four major areas in the field of radiative heat transfer. After the Introduction, there are two chapters dealing with theoretical and practical aspects of radiative properties of opaque surfaces, including a brief discussion of experimental methods. These are followed by five chapters dealing with purely radiative exchange between surfaces in an enclosure without a "radiatively participating" medium, and one more chapter examining the interaction of conduction and convection with surface radiation. The rest of the book deals with radiative transfer through absorbing, emitting, and scattering media (or "participating media"). After a detailed development of the equation of radiative transfer, radiative properties of gases, particulates, and semitransparent media are discussed, again including brief descriptions of experimental methods. The next eight chapters cover the theory of radiative heat transfer through participating media, separated into a number of basic problem areas and solution methods. And, finally, the book ends with three chapters on combined-modes heat transfer and the emerging fields of inverse and nanoscale radiative heat transfer.

I have attempted to write the book in a modular fashion as much as possible. Chapter 2 is a fairly detailed (albeit concise) treatment of electromagnetic wave theory, which can (and will) be skipped by most instructors for a first course in radiative heat transfer. The chapter on opaque surface properties is self-contained and is not required reading for the rest of the book. The five chapters on surface transport (Chapters 4 through 9) are also self-contained and not required for the study of radiation in participating media. Similarly, the treatment of participating medium properties is not a prerequisite to studying the solution methods. Along the same line, any of the different solution aspects and methods discussed in Chapters 14 through 21 may be studied in any sequence (although Chapter 21 requires knowledge of Chapter 8). Whether any of the last three chapters are covered or skipped will depend entirely on the instructor's preferences or those of his or her students.

I have not tried to mark those parts of the book that should be included in a one-semester course on thermal radiation, since I feel that different instructors will, and should, have different opinions on that matter. Indeed, the relative importance of different subjects may not only vary with different instructors, but also depend on student background, location, or the year of instruction. My personal opinion is that a one-semester course should touch on all four major areas (surface properties, surface transport, properties of participating media, and transfer through participating media) in a balanced way. For the average U.S. student who has had very little exposure to thermal radiation during his or her undergraduate heat transfer experience, I suggest that about half the course be devoted to Chapters 1, 3, 4, 5, plus parts of Chapters 7, 8 and/or 9, leaving out the more advanced features. While the Monte Carlo method of Chapter 8 may be considered an "advanced feature," I have found it to be immensely popular with students, and at the same time gives exposure to an engineering tool of fast-growing importance. The second half of the course should be devoted to Chapters 10, 11 and 12 (again omitting less important features); some coverage of Chapter 14; and a thorough discussion of Chapter 15. If time permits (primarily, if surface and/or participating media properties are treated in less detail than indicated above), I suggest to cover the P_1-approximation (which may be studied by itself, as outlined in the beginning of Chapter 16), the basic ideas behind the discrete ordinates method, and/or a portion of Chapter 20 (solution methods for nongray media).

With the addition of new material, and in spite of omitting outdated items, the third edition has again grown considerably over its previous version. I would like to thank several of my friends and colleagues from around the world who guided me in the decision making process for many of the changes in this book, viz., A. Charette (Quebec), P. Coelho (Lisbon), K. Daun (Waterloo, Canada), L. Dombrovsky (Moscow), W. Lipiński (Minnesota), S. Mazumder (Ohio), K. Mitra (Florida), L. Pilon (California), S. Thynell (Pennsylvania), and R. Viskanta (Indiana). Of course, if you put ten professors into a room, you are bound to get a minimum of twelve different opinions: I hope they will forgive me if not all their suggestions were followed. Z. Zhang (Georgia) supplied a small MATLAB® program, from which Figs. 24-7 and 24-8 were generated, which is gratefully acknowledged. And a special thank you goes to two of my young colleagues: Wojciech Lipiński for writing the two sections on *Radiative Properties of Porous Solids* (Chapter 13) and *Radiation in Concentrating Solar Energy Systems* (Chapter 22); and also Kyle Daun for many hours spent helping me to rewrite the chapter on inverse radiation (Chapter 23). Thanks also go to two of my postdoctoral researchers, J. Cai and R. Marquez, who converted the more basic computer codes (Appendix F) to MATLAB®. Finally, I would like to posthumously acknowledge Eileen Stevenson, my wonderful secretary from many years ago who typed the first edition, and who recently passed away at much too young an age.

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