PREFACE

This book is intended as a textbook for a graduate-level course for students in engineering. It is hoped that it will also find use as a reference text for practicing thermal analysts and designers of heat transfer equipment. The book is an accumulation of my lecture notes from thirty years of regularly teaching a thermal radiation course at the University of Waterloo. It also draws on a somewhat longer experience of research in heat transfer and solar energy applications.

During the early part of that lecturing experience, I had followed the approach used in several popular texts. Despite the excellence of these texts, I was never fully satisfied with their approach, which I will call here the traditional treatment. The traditional treatment divides radiation into two separate parts: the first treats radiation as a surface phenomenon, and the second (dealing with participating media) treats radiation as a volumetric phenomenon, which it truly is. This meant that the fundamental equation of radiative transfer—the Radiative Transfer Equation or RTE—was not introduced until more than halfway through the course, when the volumetric treatment is undertaken.

In the latter part of my lecturing experience, I experimented with a more holistic approach, wherein the volumetric treatment and RTE are introduced at the beginning of the course, and the treatment of radiation as a surface phenomenon is developed later as a special case. I found this approach gave the students a more fundamental understanding, and also that it was a more efficient, in that more material could be covered in one course. Moreover, given that the students had been exposed to the traditional treatment at the undergraduate level, they found the holistic approach at the graduate level gave a refreshing contrast—an altered perspective that made the subject more interesting.

It is admitted that this approach may not be suitable for all. The students must spend longer on fundamentals before making engineering heat transfer calculations. Some students prefer the topics to be more concrete and directly relevant. Professors who are especially concerned for these students, or whose natural proclivities are also along these lines, will want to continue to use the traditional approach. But for those professors who prefer the advantages of the holistic approach, this book should provide a useful text.

There are several other novel aspects to the text, including the manner of handling radiant calculations. In times past, no textbook formula designed for routine problem-solving would ever contain a definite integral. But now every graduate student and serious thermal analyst has a personal computer, and moreover, software packages, such as Mathcad® and Mathematica®, are readily available—many universities have site licenses for one or both of these packages. So now textbook formulas can realistically contain definite integrals (as well as the inverse of high-order matrices) because they are easy to set up and can be quickly evaluated numerically. This new practice is adopted in this text, wherever applicable. More on this topic is given in the Introduction.

Principal among these numerical integrations is spectral integration, whether over surface properties or over the complex gaseous radiation properties. But just as important is the area integration associated with the form factor. In this book, the well-known formulas for form factors are supplemented by numerical methods of double or quadruple integration, using the parametric representation of surfaces. The principle of parametric surface representation is explained in an Appendix (Appendix A), which also gives a catalog of parametric representations suitable for quick entry into Mathcad. With this data, form factors between more than 100 combinations of pairs of surface-types can be readily calculated, regardless of the orientation and placement of the surfaces with respect to each other. Although the actual calculations take a few minutes for the computer to complete, the computational time is still fast enough for course-work problem-solving.

A set of problems is included at the end of each chapter. Some of the problems require the use of Mathcad, and the wording of the problems has been designed to make it easy to spot the ones that will require Mathcad or a similar software package to complete.

The recent "smoothed-band" model of gaseous radiation and the availability of Mathcad and similar packages has enabled the isothermal gas enclosure to be handled in a relatively simple way—without the band-energy approximation and the mean beam length approximation. This is expounded on in Chapters 20 and 22.

It is not possible to do a proper coverage of radiation without getting into some aspects of quantum mechanical theory and electromagnetic wave theory. Whereas the other modes of heat transfer draw only on classical (prequantum) physics, the same is not so true of radiation.[1] I have strived to cover enough quantum mechanical and electromagnetic wave theory to meet the needs of the student.

Experience has shown that the material covered in this book can be completely covered in about 39 lectures, which is the length of an academic term at the University of Waterloo. Nevertheless, if a shorter time is available, some sections can be cut without losing the grand sweep of the material. Supplementary material, say on current research topics, such as the incorporation of radiative effects into the current CFD codes, can be added by the instructor

[1] Thermal radiation is very much bound up with the history of modern physics. It had no adequate explanation in classical physics. Planck's derivation of his Radiation Law was the first break from classical physics and the start of quantum mechanics. Electomagnetic wave theory, while older and not so revolutionary as quantum physics, was a necessary prerequisite to a fundamental understanding of thermal radiation.

when additional time is available or when an enriched treatment is sought. No material has been included on the important area of radiation measurements. At Waterloo, a separate laboratory exercise accompanied the lectures.

My own experience has been that the study of thermal radiation not only provides the wherewithal to solve engineering heat transfer problems—important as that is. It also provides a new and exciting way of looking at the world around us. For example,it exposes us to some revolutionary branches of physics, and it explains how the light from objects around us actually come to our eyes. I have attempted to capture some of that excitement in this book.

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