MODELING AND APPROXIMATION IN HEAT TRANSFER

Engineers face many challenges in design and research involving complex thermal systems. In practice, modeling and associated synthesis very often precede sophisticated analysis or even the need for precise results. *Modeling and Approximation in Heat Transfer* describes methods for reaching engineering models of physical systems by approximating their characteristics and behavior. This textbook provides a systematic discussion of how modeling and associated synthesis can be carried out by identifying key first-order effects, by making order of magnitude estimates, and by making bounding calculations. This book aims to help students develop greater facility in breaking down complex engineering systems into simplified thermal models that allow essential features of their performance to be assessed and modified. Topics include steady and unsteady heat conduction, convective heat transfer, heat exchangers, and thermal radiation. Many worked examples are included.

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Cover photo: View of the space shuttle Atlantis, reentering the Earth's atmosphere, photographed by the International Space Station (courtesy NASA). See homework problem 3.12 for approximate model of reentry heat transfer.

To

Judith Kidder Glicksman and Theresa Kavanaugh

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Preface

Many excellent textbooks on thermal science have been written, often including detailed physical theory and mathematical analysis. Yet, most of these texts lack any systematic discussion of how modeling and associated synthesis can be carried out – in engineering practice, these steps very often precede mathematical analysis or the need for precise results. Some may argue that these initial stages of problem formulation are a skill that cannot be taught formally and that can be acquired only through long experience with engineering problems. The present authors disagree with that premise.

During the past 15 years, we have developed a course on modeling and approximation of thermal systems, which we have offered to graduate-level engineering students at MIT. This text has evolved from our experience in teaching that course. The course owes much to the traditional structure of the MIT doctoral qualifying exams as well – which many outside MIT are surprised to learn focus primarily on assessing a candidate's ability to think in physical terms, rather than on his or her ability to do fancy calculations! We have found that after completing this course students have greater facility in breaking down complex engineering systems into simplified thermal models that allow essential features of the system's performance to be assessed and modified.

Learning this material requires working through problems that apply these ideas in an engineering context. We have included end-of-chapter problems of this nature. Most are open-ended without a unique "correct" solution and some appear to be very complicated. We have found that students who take the time to work through these exercises come away with a good understanding of the material. In our own teaching, we generally assign the problems to students to work ahead of class meetings, and we devote a substantial amount of the classroom time to discussing how to approach the problem, the possible solutions, and the various factors and complications that they contain. This discussion involves the entire class in a question-and-answer format.

The minimum background assumed of readers of this book is a one-semester undergraduate level subject in heat transfer, along with its normal prerequisite subjects in thermodynamics and fluid mechanics. Prior study of heat transfer at the graduate level will certainly be helpful as well. In addition, students who have had the opportunity to do some work on the design or experimental characterization of thermal systems are also likely to have experienced the challenges that this book undertakes to address.