PREFACE

The theory of heat conduction has been an integral part of heat transfer teaching and research for over a century. In typical undergraduate heat transfer courses, the treatment of heat conduction is usually limited to the basic theory and elementary applications. The more advanced material is reserved for presentation in advanced heat transfer courses or courses that are exclusively devoted to heat conduction. Such courses are almost always devoted to the teaching of classical mathematical techniques, such as the methods of separation of variables, Laplace and Fourier transforms, integral methods, perturbation theory and Green functions. Increasingly, numerical techniques such finite differences and finite elements are being incorporated to complement the discussion of the classical methods. This presentation methodology is reflected in several excellent textbooks on heat conduction that are currently available.

The learning and implementation of classical mathematical techniques entails tedious algebraic manipulations. While they illuminate the elegance of mathematics, they often take the focus away from understanding the physics of the analysis. Furthermore, even if the problem is amenable to an analytical solution, the algebra is often too intense or laborious. This difficulty can now be surmounted with the use of symbolic algebra packages such as *Maple* or *Mathematica*. These programs are virtually revolutionizing the teaching of calculus and differential equations. However, their use in teaching and research in the traditional disciplines of engineering is still in its infancy.

The aim of the present book is to demonstrate how the use of *Maple* not only facilitates the study of traditional topics in heat conduction theory but also opens the door for introducing more creative and challenging problems at both undergraduate and graduate levels. The choice of *Maple* in favour of *Mathematica* is a personal one and no way reflects the superiority of *Maple* over *Mathematica.* Besides its symbolic analytic capability, *Maple* also has powerful numerical and graphical interfaces which make the software very versatile. This book was written with *Maple 8* but the material should easily transition, often without any modification, into any future version of the software.

The book can be used either as a self-contained study of heat conduction theory or as a supplement to a standard heat conduction textbook. In either case, an undergraduate background in heat transfer and differential equations would be helpful. The material has been class tested for several years and proven effective in enhancing student's learning of heat transfer. The students found that the learning of *Maple* demanded only a modest amount of effort but the broadened their analytical ability considerably. Most of them also enjoyed using *Maple* in other engineering courses.

The opening chapter of the book, which is devoted to an overview of *Maple*, is designed to familiarize the reader with the basic syntax and features of the software. For an in-depth presentation of *Maple*, the reader may refer to the references that are cited throughout this book.

The second chapter illustrates the use of *Maple* to study and evaluate the mathematical functions that are commonly encountered in heat conduction analysis. Here the emphasis is on error functions, gamma and beta functions, Bessel functions, Legendre functions, hypergeometric functions and the exponential integral function. Chapter 3 shows how *Maple* can be used to solve algebraic and transcendental equations that arise in heat conduction problems. The study of elementary one-dimensional steady state conduction with *Maple* is presented in chapter 4. The topics include conduction in plane wall, hollow cylinder, hollow sphere and truncated conical section. The chapter also discusses heat conduction with uniform heat generation. The more advanced topics in one-dimensional steady conduction, such as variable thermal conductivity, non uniform heat generation, radiative-convective boundary condition and optimization of thermal systems are covered in chapter 5. A comprehensive discussion of the analysis and design of extended surfaces appears in chapter 6. Included are straight fins, spines, annular fins, finned arrays, and convecting-radiating fins. Chapter 7 focuses on two-dimensional steady conduction. Here the method of separation of variables and the finite difference method are implemented in the *Maple* environment for Cartesian, cylindrical, and spherical geometries. The last chapter treats the topic of time dependent conduction. The presentation begins with lumped thermal capacity models with constant properties. Temperature dependent specific heat, radiative cooling and the temperature dependent heat transfer coefficient are analyzed with the help of *Maple*. Time-dependent conduction in a semi-infinite solid is studied with the method of the Laplace transformation and the similarity technique, both of which are implemented in *Maple*. Solutions for the transient response of an infinitely long plane wall and an infinitely long solid cylinder, both experiencing surface convection, are then considered. Here the opportunity is taken to illustrate the implementation of the method of separation of variables, the explicit finite difference method, and the implicit finite difference method. Finally, the method of complex combination is used to study the oscillatory behaviour of a convecting rectangular fin with periodically varying base temperature.

The book is replete with examples that range from elementary to advanced. Some of them are chosen from the contemporary heat transfer literature while others are novel extensions of known problems. A careful study of these examples should readily suggest and motivate the reader to exploit *Maple* to explore new and challenging problems for either individual research or as assigned in undergraduate and graduate heat conduction courses.

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A. Aziz