Preface to the Third Edition

APPROACH

This new edition represents a significant shift from the previous version in the approach to this subject, which should not be unexpected with the addition of a new author. The shift is not a discontinuous one but represents an evolution over the last 15 years, incorporating the original ideas and extending them to a more comprehensive approach to the topic.

In his original preface, Prof. Gaskell, who passed away in 2013, posited the need for materials engineers to study transport phenomena and, given the constraints of the materials science and engineering (MSE) curriculum, to do so in one semester. Heat and mass transfer and fluid flow in materials processing control microstructural development and the associated distribution of properties in engineered products and so understanding transport phenomena is absolutely critical to the understanding and design of those processes and products. To support this activity, Prof. Gaskell wrote this text and developed his third-year course at Purdue University. Regarding the focus of his text, he wrote in his first-edition preface that

> a careful balance must be made between an explanation of the fundamentals that govern the dynamics of fluid flow and the transport of heat and mass, on the one hand, and, on the other, illustration of the application of the fundamentals to specific systems of interest in materials engineering.

His response to this challenge for an introductory class was to focus the first two editions of the text on the development of the governing equations and the small set of exact solutions. It is my view that he correctly eschewed a more handbook-style approach that tends to center on a catalog of processes, with *ad hoc* descriptions of associated transport phenomena included as needed, in favor of a more strictly fundamental approach, inspired by Bird, Stewart, and Lightfoot's *Transport Phenomena* (1960). The understanding of the origins and solutions of the governing equations is vital to their application to materials processing, either in closed form or by numerical analysis.

However, I believe that being restricted to this approach gives necessary, but not sufficient, coverage of the subject in response to the needs of MSE students and practicing materials engineers, and that it can be improved in two ways. First, the previous approach gives little explicit motivation or demonstration for why this subject is in the MSE curriculum. Students who have used this text at Purdue and elsewhere have repeatedly made this point, so a case must be made for the allocation of scarce time in the curriculum to this subject instead of others. *New examples of processing in the text and end-of-chapter problems are included to show the applicability of this topic and help to justify its place in the plan of study. As part of this effort, examples are given from across the broad range of materials, including the processing of metals, ceramics, polymers, and electronic materials*. The second aspect addressed in this edition is the need for more substantial discussion of the physical basis and meaning of the derived balance equations, which are the bedrock of the previous editions, and how to apply them to practical problems. These equations should be viewed as balances of physical phenomena, and my teaching approach in many cases has been to begin with *scaling analysis to determine the order of magnitude of these phenomena and their interrelationships* before attempting mathematical or numerical solutions. Further exploration is by approximating complex reality to one or more simple problems, which can be solved and from which solutions we can draw conclusions about the system's behavior. This simple approach focuses the student on fundamental physics and provides the rationale for model simplification during application to practical problems. It helps the student connect the theory represented by the mathematics to the real world. In fact, in industrial settings, the scaling of a practical problem, perhaps followed by the approximate solution of a simplified model, frequently provides sufficient information to make an engineering decision. When not sufficient, the preliminary scaling and approximate analysis are still useful to understand the problem, guide development of a numerical model, and to interpret its results. I strongly believe that including practical examples and the practice of problem-solving methods adds depth to the framework provided by Prof. Gaskell in the previous editions and brings it more in line with a more materials processing–focused teaching approach. Many former students who took the course on which this text is based have reported the utility of this approach in exploring real situations in an industrial context.

USE OF THIS TEXT

This text is aimed at junior/senior-level engineering undergraduates and students early in their graduate studies, as well as practicing engineers interested in understanding the behavior of heat and mass transfer and fluid flow during materials processing. It assumes familiarity with calculus, basic differential equations, and introductory thermodynamics and mechanics. An introductory course in materials science covering phase diagrams, time-temperature-transformation diagrams, and basic microstructural forms is very useful for understanding many applications. The course is a useful prerequisite to any materials processing lecture or lab course. The text is designed primarily for materials engineering education but will also be a good reference for anyone desiring a one-semester treatment of introductory fluids and heat transfer or for the practicing materials engineer looking for insight into the transport phenomena controlling her process. In all cases, the main purpose is to understand the basic physics of transport phenomena and how to model and apply them to materials processing.

Looking through many syllabi for courses at many universities that could use this text, I discovered many different orders and choices of topics. Looking through a variety of options, certain general restrictions became apparent:

- fluid mechanics should be before convection,
- conduction should be before convection heat transfer,
- mass diffusion should be before convection mass transfer, and
- convection heat transfer should be before boiling.

One difficulty with any text is convincing students it is worth their time to read it. To incentivize reading the book, I recently added daily reading quizzes to the course. These short evaluations, usually just a few multiple choice or true/false questions, are taken online and graded by the course management software used at Purdue. They have been an effective tool to encourage reading before lecture and have improved class participation and quiz scores.

As a last note on teaching, I will address the evaluation of the students in this course, for which I have tried two different methods for testing. The first is to require weekly homework assignments, three hour-long midterms, and a two-hour final exam. This practice is common and does have the advantage of giving students direct incentives to work problems, which is the best way to learn the material. However, there are some difficulties. Many students tend to rely on others for their homework and so do not pay serious attention to the class for the five weeks between exams, but the material is too difficult to cram for exams three or four times a semester. In recent years, we have still assigned homework problems, but we did not collect the work. While it seems counterintuitive, the students have proven to be more likely to do their own work because of another structural change: we replaced the few midterms with biweekly, 25-minute quizzes. Having to perform as individuals on a much more frequent basis seems to keep the students' attention, and their overall performance has improved (with no significant change in the types or total number of test questions).