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REVIEWS

Mass Transport Phenomena. By C. J. GEANKOPLIS. Holt, Rinehart and Winston, 1972. 495 pp.

Momentum, Energy, and Mass Transfer in Continua. By J. C. SLATTERY. McGraw-Hill, 1972. 609 pp. $19.50.

Mass transfer is a subject that is central to analysis in chemical engineering. Problems ranging from the design of commercial distillation equipment to analysis of diffusion in catalyst pellets abound in chemical engineering literature and often involve mass transfer in flow systems of complicated geometry. For decades the texts on mass transfer were confined to analyses of separation devices such as distillation columns and absorption towers. The complexities of such analyses are often formidable because many components and at least two fluid phases are involved. Moreover, conditions are seldom isothermal. Consequently, analyses centred on equilibrium considerations with finite rates of mass transfer accounted for by an efficiency factor or related idea. Even so, and despite other simplifications, analysis was and is an arduous affair. After computers greatly simplified the task, chemical engineers turned increasing attention toward an understanding of the nature of mass transfer and analysis of point values of concentration and mass flux.

A landmark in the turn toward fundamentals was the publication in 1960 of *Transport Phenomena* by Bird, Stewart and Lightfoot. The two works reviewed here continue this trend and are also written by chemical engineers, but there is little resemblance between these three books. *Mass Transport Phenomena* is a junior or senior level text and introduces both the scientific study of mass transport phenomena and the old familiar methods of separation equipment design, though no connexion between the two is made. The first two chapters discuss molecular diffusion and the equations of change. The equations of motion, energy, and continuity are derived and presented in both vector and component form, and special emphasis is given to multicomponent and binary fluids. Chapters 3–5 concern molecular diffusion, and cases involving chemical reaction are discussed. Chapter 6 concerns mass transfer in laminar and turbulent flow; chapters 7 and 8 concern interphase mass transfer including chemical reaction, and chapter 9 discusses methods of separation processes. Chapter 10 is on the use of analog computers to solve differential equations. Many examples are worked out in detail, an ample number of problems are given at the end of each chapter, and many references are given. I found the discussion of mass transport with chemical reaction in two phases in chapter 7, though elementary, to be particularly lucid and enlightening.

The book suffers from several flaws. First, knowledge expected of students is very uneven. For example, an explanation of solution of algebraic equations by matrix algebra is so short (one page) that students not already familiar with matrix algebra would be confused. (Moreover, vectors are not defined until the next chapter.) Later in the book is an explanation of evaluation of an integral by graphical integration. Second many statements are made without explanation. Such terms as tensor and elliptic and parabolic differential equations are used without explanation or definition. Repeatedly we encounter such phrases as, "This is called Knudsen diffusion; the Knudsen diffusivity is independent of pressure and is calculated by $D_{KA} = \dots$". There is then no discussion whatever of origin, assumptions, or constraints of the equation.

Finally, there are many statements that are misleading or incorrect. The treatment of constitutive relations (a phrase never used) is particularly distressing, for the student is left with the impression that Newton's law and Fick's law are exact. Fourier's law is described as empirical though no further qualifications are given. The possibility of non-Newtonian behaviour is not even suggested. Other misleading and sometimes incorrect statements appear, particularly in discussions of turbulence.

Professor Slattery's book is aimed at graduate students in engineering. It is an attempt to present a unified view of transport phenomena through the ideas of continuum mechanics. References to C. Truesdell are frequent, especially where foundations of the subject are presented early in the book. There is an engaging preface following which the unwary student will be put off on page 2 by such statements as, "A *body* is a set; any element ζ of the set is called a particle or material particle. A one-to-one continuous mapping of this set onto a region of the space E studied in elementary geometry exists and is called a *configuration* of the body: $z = X(\zeta)$, $\zeta = X^{-1}(z)$."

The first two chapters lay the foundations of transport phenomena with great care. Knowledge of tensor analysis is essential here, and a useful appendix on tensors is provided. The remaining chapters are easier going, though still at an advanced level. Two long chapters on fluid mechanics are followed by three chapters on energy transfer, which is introduced with a chapter on those aspects of thermodynamics necessary to the careful construction of the foundations of energy transfer. Mass transfer is then introduced with the usual care followed by applications. Though the book is large, 679 pages, the subject-matter is enormous, and so some subjects are omitted. These include compressible flows, radiation, design methods, and interfacial effects. The latter omission is surprising in view of the interest of the author and the importance of this subject in chemical engineering.

The strength of this book lies in its careful exposition of the foundations of transport phenomena, its attention to mathematical detail (with exceptions to be noted), and the unified approach to three subjects usually taught separately. The excellent discussion of integral averaging and integral balances is worth special mention, and the sections on their application to flow through porous media are without peer. The discussion of turbulence, however, is outdated and contains conceptual errors which detract from the otherwise excellent discussion.

The greatest weakness of the book is its lack of adequate explanation of many concepts, especially physical ones. The stream function, for example, is given no physical interpretation, and vorticity is described in less than four lines. In several places similarity transformations are used without explanation, and

I think that the process of solution of differential equations by this technique would appear mysterious and bewildering to students. There are a number of places where references to singular perturbation theory might have cleared up ambiguities; at one point the author drops the term of a differential equation containing the highest-order derivative and then states, "But the reader is cautioned that this is an intuitive argument that may not be true in every situation. There is no theorem that says that, because a term of a differential equation is multiplied by a small parameter, the term can be neglected." There follows no mention of singular perturbation theory, which is surprising in view of the author's otherwise careful attention to literature references. In several places an equation is given or asserted with little or no explanation. For example, on page 45 we read, "In particular, a constitutive equation must be satisfied for a process in which the stress tensor and motion are given by..." and there follows a set of equations for which no explanation is given.

The book is a good reference source for the foundations of transport phenomena. In contrast to the hope expressed by the author in the Preface, however, I think it would be difficult to use as a text-book, and is well suited to self-study only if used in conjunction with a book offering greater explanation of ideas.

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