An Introduction to Fluid Dynamics and An Introduction to Mass and Heat Transfer

By Stanley Middleman, John Wiley, 1998 New York, 512 pp. and 672 pp., $99.95 each book.

T. K. Sherwood, reviewing in 1961 the newly published Bird, Stewart and Lightfoot "... probably the most important textbook on chemical engineering to appear in many years," he prophetically said—went on to comment on what he saw as an ominous tilt towards engineering science and to declare "[BSL] poses a challenge for someone to procure an equally good text dealing with the *engineering* aspects of chemical engineering" (Sherwood's italics; see Astarita and Ottino, 1995). Middleman's books are an ambitious attempt to move transport in a design-like direction. These are independent texts sharing the same philosophy; their prefaces are nearly identical and they are both tellingly subtitled *Principles of Analysis and Design*. Both books, in the words of the author are "overwritten": they both have similar formats—figures, backcover burbs, structure—and are organized in similar ways. All this strongly suggests reviewing them as one.

Fluid Dynamics (FD) is 512-page-long; *Mass Transfer and Heat Transfer* (MT + HT) is 672-page-long. Middleman's stand is clear: "as a teacher, I have found that students are more motivated by problems having a basis in commercial technology than those whose orientation is primarily mathematical or analytical," he states in the preface. The declared backcover objectives—headed by "For a Full Course in Transport Phenomena"—are to "focus on the development of a mathematical model a central part of the analysis and design of an engineering system or process," to "teach students how to develop accurate mathematical representations of physical phenomena," to "present many examples of experimental data against which the model can be compared," and to "expose students to the wide range of technologies which they may encounter in the future." Both books are wholly consistent with the goals set forth above.

Design is recurrent and the examples plentiful. On the "overwritten" issue, the author says, "[I]t should not be necessary to assign the same problems in successive years." And I believe him: there are 79 problems in the chapter on "Nearly Parallel Flows," in the FD text, and 99 in the "Unsteady State (Transient) Mass Transfer" chapter in the MT + HT text.

Both books draw on Stanley Middleman's expertise (and previous book writing) in polymer processing, biomedical engineering, microelectronics; many of his papers make their way into the book by the way of examples. And the examples cover quite a spectrum: *wasp spray, water strider insects, pasta extrusion,* manufacturing of *semiconductor wafers, drops spreading on paper, treatment of hydrocephalus,* lubrication of *knee joints,* and *environmental decontamination* appear in the FD book; a device for the *treatment of glaucoma, decaffeination of coffee beans, drying of paper, drug delivery systems, dynamics of transport in landfill barriers* in the MT sections of the MT + HT book.

Let us delve into the contents. The FD book starts with "What is Fluid Dynamics?" Then, it goes to "Statics, Dynamics, and Surface Tension" and from there on to "Forces on and Within, and Flowing Medium." Chapter 4, more conventional, but with a substantial 64 pages and 87 problems, covers "Conservation of Mass and Momentum." The entire text Chapter 5 is devoted to "Dimensional Analysis and Dynamic Similarity." Chapter 6 on "Nearly Parallel Flows," as mentioned already, is a substantial 58 pages; Chapter 7 on Unsteady Flows covers the obligatory material, but with problems on stability of liquid jets and leveling on surface disturbance on thin films, and the application of the latter being a magnetic recording system. The next two chapters, "The Sream Function" and "Turbulent Flow and the Laminar Boundary Layer" are somewhat more conventional, but "Porous Media" gets the entire Chapter 10, before one reaches the finale in Chapter 11 with "Macroscopic Balances," a hefty 55 pages, with 64 problems. All chapters start with a sketch and end with a summary.

The MT + HT text opens in a similar vein and follows the same structure: "What is Mass Transfer?" (Chapter 1), "Fundamentals of Diffusive Mass Transfer" (Chapter 2) and continues with "Steady, and Quasi-Steady Mass Transfer," and then "Unsteady State (Transient) Mass Transfer"—with a record of 99 problems—followed by Chapter 5 on Diffusion with Laminar Convection and Chapter 6 on Convection Mass Transfer Coefficients. Macroscopic topics are covered in the next two chapters, "Continuous Gas/Liquid Contactors and Membrane Transfer and Membrane Separation Systems," moving them to the Heat Transfer section of the book. Here the symmetry of the structure is a bit lost—the introduction to HT is only two pages long. The sequence continues with "Heat Transfer by Conduction," "Transient Heat Transfer by Conduction," "Convective Heat Transfer," before reaching an entire chapter on "Simple Heat Exchangers." The next two are somewhat standard: Chapter 14 is on "Natural Convection Heat Transfer," and Chapter 15 deals with "Heat Transfer by Radiation." The finale is Chapter 16, "Simultaneous Heat and Mass Transfer." MT + HT has several appendices; only a short appendix is common to both books.

The examples and how they are used are the best features of the books. Comparing model results to real data and weaving in references to journal articles (and even hints on how to read the literature) are a plus. Of course, even an excellent book can be improved, and improvements may fall in the category of things that can or should be fixed, things that have to do with the authors's taste and philosophy (usually nonnegotiable), and finally the inevitable things that the reviewer thinks ought to be in the book but are not. Comments along the lines of the first and last items in this list are offered in the fervent hope that the book will have a second edition.

The index should be easy to fix. Trying to rediscover specific examples—as I experienced in the preparation of this review—is very difficult. Surprising as it may seem, absolutely *none* of the randomly picked examples listed above in italics (the only exception being "knee") is to be found in the table of contents of these books! An index of examples might be a good idea. Another minor feature is the number of problems of the "it is not difficult to show" category. It is most annoying to find them referred to in the text as, e.g. "See Problem 6.23," as if they could help, only to find that the entire statement of Problem 6.23 is "Derive the criterion given by 6.4.15."

Writing style and philosophy are nonnegotiable issues. The writing style, however, goes beyond using first-person singular. Two examples, one short, one long: "When the going gets tough, the tough learn Greek!" exults the text at one point. The long one: "Look, this is a tough problem... and it's easy to get lost in the math. Don't give up. There is some really important stuff to be learned here, if you'll stick with it. But this doesn't mean you have to torture yourself. This is a good time to take a break. Eat some chocolate and watch the Three Stooges for 30 minutes. Then come back refreshed." Some readers will like this, others will not. This is so much an integral part of the personality of the text that a review would not be complete leaving this out.

Now on to philosophy. Starting the second volume with Mass Transfer is an unconventional, but a defensible, choice. Deeper choices have to do with the question of starting from specifics. Surface tension is brought up first in terms of a specific example, before going into the general (Young-Laplace equation). People interested in education may get in the debate of which approach works best and it is almost pointless to try to draw comparisons; many books, especially graduate-level books, go from the general to particular. This one, however, is decidedly of the point of view of adding complexity one layer at a time. Another point is whether or not macroscopic balances (especially in the FD text) should go at the end (the most popular choice) or if they should receive more play (it is about 19% in the FD text).

There are few items that belong to the category, "I wish they could be included in subsequent editions." This is highly idosyncratic. There are, for my taste, too few actual pictures of flows (only one that I remember). "We consider only Newtonian fluids in this text," the text states unequivocally (p. 67), even though there are some problems with ketchup and blood. I think, however, that a chapter of Non-Newtonian fluids may be a good idea, at least to point people in the right path. Ditto for non-Fickean transport, although this can be done with a few examples (and, unless I missed it, I could not find a clear statement of $\delta \sim t^{1/2}$; in fact, the term "penetration" does not appear in the indices). Much easier would be to incorporate (missing) Taylor vortices (in p. 149) and adding them to the stream function chapter, add a couple of examples dealing with moving boundaries, such as melting; mention Taylor diffusion (of practical importance), something about Kolmogorov scales (of practical importance as well), percolation concepts, and possibly something on transport with reactions constrained by equilibrium considerations. The graph of critical capillary number vs. viscosity ratio (G.I. Taylor) has my vote as well on practical and educational grounds. The list could be endless and should not cloud the author's objective. However, the structure of the book makes additions simple and one can see how it can grow.

Polishing a book of this magnitude is a serious undertaking and one that only book authors can possibly understand. I am sure that there is more repetition here than I have been able to find (e.g., Figure 1.17 appears again as 8.2.6). Improving a text such as this is a long and laborious process. Undetected inconsistencies and errors have to wait for instructors and students to go through the material. This is the hardest period for an author: waiting to see the text covered with yellow markers and notations at the margins! Taken together these books cover lots of territory; examples cover biomedical engineering, environmental problems, microelectronics, polymer processing, and conventional aspects of chemical engineering. The examples alone justify using the book and I, for one, will definitely consider them for undergraduate courses, because I have to agree with Middleman's observation: today's students are more motivated by problems having a basis in commercial technology. The books get this point across. The desirability of having a mathematical model as the central aspect to the analysis and design of engineering systems as well comes across. The issue of model evaluation is also pervassive throughout the book. All these are laudable goals, and my feeling is that the author has succeeded in his aims.

Literature cited

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