ChE book review

Heat and Mass Transfer for Chemical Engineers: Principles and Applications

By Giorgio Carta
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This textbook on heat and mass transfer for chemical engineers assumes that students have already taken a fluid mechanics course. The material can be covered in a typical one-semester junior-level course. Considerably more material is devoted to mass transfer than heat transfer because it is often more relevant to the chemical engineer. The book's stated goal is to provide a conceptual understanding of the phenomena along with the tools needed to apply the concepts to practical problems.

Fluid mechanics knowledge is assumed in sections that discuss laminar boundary layers and in sections that explain analogies between turbulent momentum transfer and turbulent heat or mass transfer. Familiarity with laminar velocity profiles in various geometries is also assumed.

The book covers heat transfer in chapters 1-7 and mass transfer in chapters 8-16 with many of the mass transfer chapters being close parallels to corresponding heat transfer chapters. Radiation heat transfer is not covered beyond a very brief introduction. The topic of heat transfer is motivated in chapter 1 by an exercise that discusses the limits of what can be done with only the concepts of mass and energy conservation. By knowing the inlet and outlet temperatures, heat capacity, and mass flow rate of a process stream flowing through a heat exchanger, we can determine the needed heat transfer rate. This however tells us nothing about how large the heat exchanger should be or how it should be configured. This is where heat transfer concepts are needed. Likewise, the section on mass transfer is motivated in chapter 8 by considering what is needed beyond a material balance and phase equilibria to design a gas absorber.

Theory is integrated with several in-depth discussions of applications. For heat transfer, chapter 4 is devoted to the analysis of fins that are used in extended-area heat exchangers while chapter 7 discusses the design of double-pipe and shell-and-tube heat exchangers, although in less detail than in a typical unit operations textbook. The final three chapters in the mass transfer section are devoted to mostly mass-transfer-driven separations applications. Chapter 14 covers the design of packed-bed gas absorption and stripping columns, chapter 15 on coupled mass transfer processes gives a detailed treatment of the transport in ion-exchange beads when internal diffusion controls, and chapter 16 covers mass transfer with reaction, including a very nice development of the governing equations needed to design a reactive absorption column.

The differential equations of mass, energy, and species conservation are derived in rectangular coordinates, and the cylindrical and spherical coordinate versions are also presented in summary tables. It is suggested that the solution of the full 3D transient equations is best accomplished by computational tools such as COMSOL or FLUENT, the exceptions being the lumped capacity method when external resistance dominates and Newman's rule for simple 3D shapes when internal resistance dominates. The book does not discuss any numerical methods for solving 2D or 3D problems but focuses on analytical methods for steady and pseudo-steady 1D problems and analytical series solutions or chart methods for transient 1D problems. Mathematica notebooks are provided as supplementary material for students to use to compute the series solutions. The general conservation equations are simplified and non-dimensionalized for the case of a steady laminar boundary layer to derive the dimensionless groups that govern convective heat or mass transfer. Heat and mass transfer coefficient correlations are then presented for practical cases.

The book makes heavy use of example problems and, in some cases, generally useful equations are developed only inside of example problems. Although this is useful in motivating the equation, it can obscure the organization of topics in places. The author is clearly encouraging a method of solving problems from first principles rather than relying on a list of pre-compiled solutions for every possible case.

One of the prominent problem-solving tools emphasized in the book is the use of literature. End-of-chapter problems often ask students to look up properties in *Perry's Handbook*[1] or find some information from a referenced journal article. In some cases, they need to compare their answer for a problem to a value from specified literature. Select physical property data for liquid water and air are provided in an appendix while students are directed to several standard resources for the physical properties of other substances. Supplementary materials include 57 Mathematica® notebooks, with notebooks for computing complicated formulas, generating figures and tables, and solving example problems.

The end-of-chapter problems are limited in number, averaging 8 per chapter, but are often realistic and somewhat open ended. Many of the end-of-chapter problems require significant interpretation and may be solved in more than one way. They often require incorporation of methods from prior chapters in the book or from prior courses. Students will likely require significant guidance for many of these problems.

In summary, Dr. Carta's textbook clearly covers the essential concepts in heat and mass transfer, motivates the concepts with common chemical engineering applications, and encourages the development of important problem-solving skills.

REFERENCES

1. Green D and Southard M (2019) *Perry's Chemical Engineers' Handbook,* 9th edition. McGraw Hill, New York, NY. ❐