

the problem of minimum reflux, and thermodynamic relationships for multicomponent mixtures.

There are also chapters on the fluid mechanics and mass transfer efficiency relationships of commercial equipment, including the design of sieve and valve trays.

The approach used throughout the book is to begin with established theoretical relationships such as the First Law, and then proceed with complete mathematical derivations of all the equations required in practice.

There are numerous numerical examples, as well as many problems for classroom and homework assignments. There is also available, from the publisher, a "Solutions Book" to the problems, free to educators. □

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## NONLINEAR ANALYSIS IN CHEMICAL ENGINEERING

*By Bruce A. Finlayson*  
*McGraw-Hill Chemical Engineering Series*

*366 pages*

**Reviewed by**  
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This graduate-level text, which provides an introduction to modern methods of obtaining solutions to nonlinear ordinary and partial differential equations, is a welcome addition to the ranks of chemical engineering mathematics books. The author's aim is to teach students how to apply such techniques as perturbation, orthogonal collocation, finite difference and finite element methods to typical chemical engineering problems. He demonstrates these using case studies drawn largely from his own experiences in chemical reaction engineering, heat transfer and polymer flow investigations.

In a brief introduction (Chapter 1) the author illustrates the types of equations considered in this book: initial-value and boundary-value ODEs, parabolic PDEs and elliptic PDEs. Hyperbolic PDEs are, unfortunately, not covered.

In Chapter 2 a short discussion of the solution of nonlinear algebraic equations is given, to provide background for the methods which follow in later chapters. Only the successive substitution and Newton-Raphson methods are presented, and some convergence proofs are given. No worked examples are provided.

Chapter 3 presents standard methods for initial-value ODEs with special attention being paid to concepts of step-size control, stability and stiffness. Computer subroutine packages are examined and a comparison of methods is made. This chapter is a reasonable review for those familiar with the material, but will make rather dry reading for beginners. The presentation is similar to that in mathematics texts, and no chemical engineering examples are worked out to illustrate the methods.

The main value of the book lies in the final three chapters, which together make up two-thirds of the whole. Chapter 4 deals with boundary-value problems, while Chapter 5 and 6 treat parabolic and elliptic PDEs respectively. Each chapter follows the same pattern: the various methods are introduced through such examples as diffusion and reaction in a catalyst particle and packed bed reactor analysis, some case studies are described, and a comparison of methods is made based on operation counts and convergence rates. At times the discussion of errors and computation times seems rather lengthy for a text directed to engineering students.

Particular attention is paid to the method of orthogonal collocation for spatial approximation in Chapters 4 and 5, especially when combined with a finite element approach. In Chapter 6 the Galerkin finite element method is thoroughly described, different types of element being illustrated and compared.

At the end of most chapters the author provides study questions, homework problems, a short bibliography and some references. The study questions give the reader a convenient "check list" of the more important points in the development, while the homework problems serve to extend the formal material. Many of the problems ask for derivations of results used earlier, while other extend the case studies, often requiring the use of FORTRAN computer programs provided in an appendix. Some of these programs are general matrix inversion subroutines, while others solve specific problems.

The layout of the book makes it pleasant to read; the text is interspersed with tables and diagrams to illustrate the results, and the print does not tax the eyes. There seem to be fewer typographical errors than one might expect in such a mathematical work. Professor Finlayson's style is clear and direct, making the book suitable even for beginning graduate students.

In summary, the book will make a good text for a graduate-level chemical engineering mathematics course oriented towards numerical methods. The instructor will find it necessary to amplify some parts of the book, and will generally wish to use a broader range of examples and homework problems than it provides. □

## AVAILABILITY (EXERGY) ANALYSIS

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This is a 100-page self-instruction manual, which is divided into four parts. In Part I, the concept of availability, also referred to as exergy, is defined, explained, and related to enthalpy and entropy. Applications are given for a number of simple physical processes. In Part II, changes in availability for chemical-reaction processes are analyzed, with the results presented in graphical form. Second-law efficiencies based on availability, are defined in Part III. Available energy costing (thermoeconomics) is considered in Part IV. An appendix tabulates standard chemical availabilities referred to 25°C, 1atm and a set of final reference products for 137 different compounds. Professor Sussman advises the reader to read the manual in a sequential manner. However, keyword or short summaries placed in the margins permit the reader to readily skip material that is already familiar.

In order to follow the presentation of material in the manual, the reader should have at least a fundamental understanding of the first and second laws of thermodynamics and be able to compute changes in enthalpy and entropy for pure compounds and ideal mixtures. Such background is generally the subject of an undergraduate course in engineering thermodynamics. In addition, some elementary knowledge of solution thermodynamics would be helpful. A pretest, included before Part I, permits the reader to determine if he/she is properly prepared to proceed. At the end of each of the four parts, exit tests, with detailed solutions, are provided to help determine if the reader has mastered the material.

In Part I, the following points are developed in a lucid, interesting, and sometimes historical fashion:

1. Both quantity and quality of energy should be considered.
2. The quality of energy refers to the fraction of that energy that can be extracted as useful work.
3. The first law makes no distinction based on the quality of energy.
4. Maximum work extraction occurs in an ideal (reversible) process.
5. The availability, which is a state property closely related to the Gibbs free energy, is a quantitative measure of the quality of energy and depends on the choice of the environmental reference (dead) state.
6. The change in availability is independent of the process path and the choice of dead state.

Throughout Part I, the chemicals considered are mainly water, air, nitrogen, and oxygen; that is, chemicals that are found in the environment. For these, examples are given of calculations of both availability and change in availability. When other chemicals are involved, only the change in availability is considered. Part I is concluded by 12 excellent examples of the calculation of availability or the change in availability for processes involving no chemical reaction. Of particular importance are some additional concepts that are presented in: 1) Example (c)iii, which illustrates the effect on availability of bringing the material of a given composition to a different dead-state composition; 2) Example (k), which defines the work equivalent of heat; and 3) Example (l), which notes that shaft work and electrical energy are exactly equivalent to availability. It is unfortunate that these very important concepts are buried in examples and are not discussed thoroughly in the main text.

In Part II, chemical reactions are considered, and it now becomes necessary to carefully elucidate the composition of the environmental reference (dead) state. This has been the subject of much discussion and controversy among researchers, with no general agreement. As an example, Gaggioli and Petit [Chem Tech 7, 496-506 (1977)] use the following dead state:

$$T = 25^\circ\text{C}, \quad P = 1 \text{ atm}$$

Gas:	Constituent	Mole Fraction
	N <sub>2</sub>	0.7567
	O <sub>2</sub>	0.2035
	H <sub>2</sub> O	0.0303
	A	0.0091
	CO <sub>2</sub>	0.0003
	H <sub>2</sub>	0.0001
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Liquid: Pure H<sub>2</sub>O

Solids: CaCO<sub>3</sub>, CaSO<sub>4</sub> · 2H<sub>2</sub>O, NaCl, etc.

Sussman uses a different dead state; namely,