53 [2.10, 4, 5, 6, 12, 13.15].—H. GREENSPAN, C. N. KELBER & D. OKRENT, Editors, *Computing Methods in Reactor Physics*, Gordon & Breach Science Publishers, New York, 1968, xi + 589 pp., 24 cm. Price $18.00 cloth, $12.00 paper.

The intent of this compendium is imparted on the front flap: "—The main function—is to help graduate students, faculty members and workers in the field [understand] formal methods [in the] formidable body of computational codes [which] have become the tools of the trade—Major numerical problems in reactor physics [are treated] in sufficient detail that the reader might gain an understanding of the fundamental methods used and the nature of the solutions." This objective has for the most part been achieved, thus making this a worthwhile addition to the literature on reactor computation.

A detailed review is precluded by space and reviewer ability limitations. A multiple-authored book might better be handled by multiple-reviewer critiques. This could, however, compound the deficiencies of such endeavors which are the inevitable change in style and level of approach, duplication, and inconsistencies arising from multiple authorship. The editors are to be commended in that these shortcomings are less noticeable here than in many other comparable endeavors.

A brief summary of each chapter with a few criticisms follows:

Chapter 1. *One Dimensional Diffusion Theory*. M. K. Butler and J. M. Cook.

The book starts with a reduction of the transport equation to the diffusion theory equation, and this is perhaps too sophisticated a beginning which might have been better placed as an appendix or as a part of Chapter 8. This is followed by a well-written introductory description of diffusion theory with a historical review.

Section 1.4 contains a concise description of the theory underlying numerical solution of 1-D diffusion problems, including some of the positivity analysis and the matrix factorization technique. There is no mention of Wielandt's fractional iteration which is the major tool for solving few-group 1-D diffusion problems, nor is there any discussion of the "stabilized march technique."

Chapter 2. *Diffusion Theory in Two- and Three-Dimensions*. A. Hassitt.

Numerical methods for solving two-space-dimension diffusion theory problems have an extensive theoretical foundation, and Hassitt does a reasonably good job of sketching some of the important areas of analysis. Limited space permits little more than a cursory look at each topic.

Difference equations are developed for various geometries, properties of the resulting matrix equations are discussed, and commonly used solution techniques are described and compared in terms of projected application.

I noted a few minor inaccuracies in this presentation: Property P7 on p. 120 is false. The matrix H on the bottom of p. 136 should include positive diagonal elements from the discretization of $-\partial^2/\partial x^2$. On the top of p. 138 it is implied that the sum of two singular matrices cannot be positive definite. This is wrong. The eigenvector deficiency in Gauss-Siedel iteration, discussed on pp. 132–133, occurs with the so-called "normal ordering" but not for the "σ_1-ordering."

Chapter 3. *Transport Theory—The Method of Discrete Ordinates*. B. G. Carlson and K. D. Lathrop.

A well-rounded description of the Sn method is given in sufficient detail to be useful with little supplementary reading. The equations are developed in terms of discrete variables and then directly from the transport equation in conservation

form. Angular quadrature coefficients are discussed and various approximations and simplifications are examined. Solution techniques are evaluated, numerical examples given, and extensions to integral transport theory and adjoint calculations are described.

Chapter 4. *Spherical Harmonics Methods.* E. M. Gelbard.

Gelbard does an admirable job of presenting a wealth of material. The bulk of the chapter is restricted to monoenergetic problems for simplicity, although multigroup extensions are cited. The P_L and double P_L approximations are derived and interface continuity and boundary conditions are considered.

The connection between Sn and P_L methods in terms of numerical quadrature formulas is developed in lucid fashion.

Solution techniques are described for the coupled first order differential equations of P_L theory. Convergence and stability are examined for various procedures. Methods for casting equations in diffusion theory form for solution are developed and the FLIP code is described in this context.

Discontinuities introduced at $\mu = 0$ by double P_L approximations in spherical coordinates are treated at length. Methods are described for avoiding anomalies which arise when one replaces a cell in a repeating array by a cylinder with reflecting boundaries. Analytic methods for solving the P_L and double P_L equations are discussed for slab-geometry. (Gelbard has advised me that the basic ideas in Section 4.5 should be credited to Aronson.)

Chapter 5. *Monte Carlo Methods in Reactor Computations.* M. H. Kalos, F. R. Nakache and J. Celnik.

This chapter describes the salient features of Monte Carlo techniques in reactor computations. No prior experience with Monte Carlo is required for an understanding of the material.

The analog procedure in which a stochastic process is simulated by history tracing of particles is described first.

A nonanalog viewpoint is then presented. A clear exposition of how history simulation and scoring enables probabilistic evalaution of integrals sets the stage for a description of "importance sampling" techniques. Subsequently, a variational approach is used to indicate how approximate adjoint functions can yield low variance results.

Miscellaneous devices such as various scoring techniques, stratification of the random variables, antithetic variates and correlated sampling for related configurations are outlined.

Some of the applications to reactor design calculations mentioned are criticality calculations, neutron thermalization, slowing down through resonances, and temperature coefficient evaluation. Salient features of pertinent programs are given.

Appendices on generating random variables and on problems of geometry round out the chapter. Unfortunately, Coveyou's elegant Fourier analysis of certain pseudo random numbers was not included here.

Chapter 6. *Reactor Kinetics Calculation.* H. P. Flatt.

The bulk of this chapter is devoted to numerical solution of the reactor kinetics equations, although some analytic and analog techniques are mentioned. The treatment is broad and informative. I would have preferred a few more introductory paragraphs on the significance of delayed neutrons with numerical values for the various time constants and sketches of flux levels as a function of time. Such funda-

mental concepts as prompt and delay critical are not discussed, for example. The reader should have some prior exposure to reactor kinetics.

The kinetics equations are expressed in integral form and various techniques for solution are considered. The method of collocation is described, and illustrated with quadratic and exponential trial functions, each of which is appropriate for a different range of criticality. An error analysis is given relating "defect" in satisfaction of the integral equation to error in the neutron number density.

Feedback effects are discussed briefly. I had hoped to find a more detailed discussion of feedback in the next chapter, but this was not the case.

Flatt points out that incentives are high for developing and evaluating numerical techniques for solution of space-dependent kinetics problems. Unfortunately, this chapter was written too soon to include recent developments along these lines. This is one of the current frontiers in reactor analysis.

Chapter 7. *Coupled Neutronic-Dynamic Problems.* R. B. Lazarus, W. R. Stratton and T. H. Hughes.

I found this to be a fascinating summary of an aspect of reactor computations with which I had no prior experience, i.e., reactor excursions. The governing equations, models and methods of solution bear little relation to the rest of the book. Nevertheless, the methodology is described with sufficient clarity for a novice, like this reviewer, to comprehend its salient features.

Excursions have been analyzed by the reactor kinetics techniques of Chapter 6, the Bethe-Tait perturbation technique, or by numerical solution of appropriate partial differential equations. The governing equations are described. They are basically motion, continuity, energy and equation of state relationships. A monoenergetic one-space-dimension mockup of neutron flux is used with a separated exponential time dependence multiplying a more slowly varying (normalized) function of space and time. The flux is obtained by solving a sequence of steady-state neutron problems.

Rigorous analysis of stability is preempted by the nonlinearity but conditions for stability of linearized equations for small perturbation of the flow variable are described.

Comparison with experiment is discussed and a flowchart is given for a sample code.

Chapter 8. *Mathematical Foundations.* J. M. Cook.

Each section in this presentation could be expanded into a full chapter, and this is the most difficult chapter in the book. Cook indicates areas for research into the mathematical foundations of reactor computations, gives a well rounded bibliography for such an effort, and sketches some of the pertinent lines of thought.

The section headings indicate the scope of the treatment: The Stochastic Process, Partially Ordered Linear Spaces, The Forward Kolmogorov Equation, The Integro-Differential Transport Equation, The Integral Transport Equation, The Multigroup Diffusion Equation, Adjoint Fluxes, Ergodicity, Existence and Uniqueness of the Stochastic Process.

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