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Book Review: Stochastic Processes in Physics and Chemistry

Stochastic Processes in Physics and Chemistry, N. G. van Kampen, North-Holland, Amsterdam, 1981. $76.50

Many years ago Irwin Oppenheim, Kurt Shuler, and I set out to write a book with the same title as that by van Kampen. For a variety of reasons the project floundered, but it is still of interest to compare our notes and completed chapters with the present monograph. That there was need for such a monograph, we took as an assured fact. The number of applications of stochastic processes in the physical sciences is enormous yet most if not all curricula for students of physics and chemistry have no requirement for a course in probability. Therefore it would seem to be useful to have an introduction to probability that possibly glosses over measure theoretic foundations but presents the important analytic ideas in the framework of applications.

The author's insights and contributions to the subject area have been considerable and his qualifications for the project could not be better. How well has he succeeded in providing a text for a graduate course? In my view teaching from this book would impose a heavy burden on any instructor because it is overly terse in many places, and leaves the development of too many enlightening results as exercises for the student. On the other hand the book is an important summary of some advanced topics, especially those in which van Kampen has made significant contributions.

The first chapter contains an introduction to fundamental definitions of probabilities, probability densities, averages, cumulants, characteristic functions, Gaussian distributions, and the central limit theorem. All of these topics are covered in 31 pages, which gives some idea of the speed at which these elementary topics are handled. If I were a bright student I would want to see a considerably more detailed treatment of a lot of this material, and if I were not so bright a student, I would be overwhelmed unless in the hands of an experienced instructor. The second chapter discusses random events in time, using a formalism developed in detail by

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Stratonovich. While shot noise is mentioned several times, no comprehensive discussion is given of this important topic. It is, at one point, made to seem to be a synonym for a Poisson process. Chapter 3 discusses the fundamentals of stochastic processes including a brief introduction to branching processes. Markov processes both discrete and continuous provide the content of the next chapter, which contains remarks very much to the point on the looseness with which many researchers convert the analysis of physical problems to the Markovian framework.

So far I have mentioned the topics that might well be found in any probability text without necessarily referring to physical systems. The next several chapters are still general but move closer to applications. These include a chapter on the master equation with a useful discussion on the asymptotic behavior of solutions and a proof of detailed balance for closed physical systems. The following chapter is on one-step processes, i.e., random walks in one dimension with steps to nearest neighbors only. This class of processes enjoys the property of allowing most of its properties to be derived in closed form and yet is applicable to several significant physical systems. In particular van Kampen summarizes the theory of first passage times for this class. Unfortunately there is no discussion of the relation of single-step to multistep processes and passage to the continuum limit. The following chapter is an introduction to the formalism of chemical rate problems in terms of Markov and semi-Markov processes, and a brief discussion of multistate processes, which I thought to be awkwardly done.

The remaining half of the book is devoted to topics to which the author has made significant contributions. These include the relation between the Fokker–Planck and Langevin equations, the asymptotic expansion of the master equation, the theory of unstable systems, fluctuations in continuous systems, and stochastic differential equations. These chapters emphasize the careful attention that needs to be paid to the relation between underlying physics and mathematics, and again show the clarity of thought that has led to the author's preeminence in the subject area.

In summary, while this is not the monograph that we would have written, it is nevertheless a valuable one. The major shortcoming, aside from a few minor errors, is that there are not enough concrete examples to put some flesh on what are occasionally some very bare bones. Some of the more interesting recent developments, such as the work of Suzuki, and the voluminous literature on random walks, receive very short shrift. On the other hand the book is the only one presently available in the subject area, and it handles many topics with clarity and insight. For that reason it certainly belongs in every physics library. The price, however, will almost certainly put it beyond the range of all but the most affluent individuals.

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