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Book Review

The Quantum Dice: An Introduction to Stochastic Electrodynamics. By Luis de la Peña and Ana María Cetto. Kluwer Academic Publishers, Dordrecht, The Netherlands, 1996, 528 pp., $224.00 (hardcover). ISBN 0-7923-3818-9.

Luis de la Peña and Ana María Cetto (husband and wife) are two well-known theoretical physics professors at the Universidad Nacional Autonoma de Mexico (UNAM) who have been working on the theory of Stochastic Electrodynamics (SED) for over twenty years. This work was anteceded by several more years of research, particularly by Luis, on the more general subject of stochastic approaches to quantum theory. As discussed in their new book, some of the key physical ideas in SED can be traced back to the very first decades of the 20th century in the work initiated by Planck, explored further by Einstein and Stern, and briefly championed by Nernst as a means to explain key aspects of quantum mechanical phenomena. Subsequently the theory was almost totally forgotten only to be next rediscovered at various times and in scattered places. SED in its modern form and in a continuous manner did not start until the fifties and sixties with the work of Paul Braffort and co-workers in France and then later on with, for example, the particularly important work by Trevor W. Marshall in England and Timothy H. Boyer in the United States. In spite of SED's mature age, *The Quantum Dice* is the first monograph ever to be dedicated exclusively to this stochastic theory.

The Quantum Dice is divided into three very distinctive parts quite descriptively labeled: *Prelude*, *Theme*, and *Coda*. Prelude (Part I) deals mainly with foundational aspects of quantum mechanics (QM), classical electrodynamics, and stochastic theories in general. Part I explores and reviews the foundations needed for the further constructing of the SED theory. It also includes a short review of related stochastic theories that may be placed under the general umbrella of the so-called "stochastic quantum mechanics," a subject in which the authors did research in the past, prior to their involvement with SED. Part I as well as Part II offer the reader a wealth of historical information in scholarly detail. Researchers should find the more philosophical discussions in Part I of interest, although there will undoubtedly be disagreements. The classical electrodynamics section is well written and should be quite useful for all.

Next comes the Theme of Part II. This is the core of the book. It deals with SED proper. Part II is initiated with a thorough discussion of the central hypothesis of SED: the existence of a classical electromagnetic zero-point field (ZPF), a classical counterpart to the electromagnetic quantum vacuum. The discussion covers both the classical stochastic and the quantum viewpoints. Next is presented a rather extensive study of the several effects that are usually attributed to the ZPF, such as the Casimir effect, the Van der Waals forces, the Lamb shift, and the Unruh–Davies effect. The derivations are done from the classical viewpoint of SED and in enough detail for the keen reader to easily follow and reproduce the calculations. Next a discussion is presented on the harmonic oscillator (HO), a basic component of many SED models. It is followed by applications of the HO to topics such as diamagnetism and even what the authors call "an attempt to model the spin of the electron." The attempt conveys to the reader several interesting but at present still inconclusive arguments of the authors and co-workers that try to bring the electron spin into the realm of SED. In a sobering tone, Part II concludes with an extensive review of the main problems and difficulties encountered by the SED theory. Readers familiar with SED may expect here an elaboration of what has become a cliché, "SED fails for nonlinear potentials." The authors in going beyond this expectation explain this failure as a breakdown of detailed energy balance when mechanical systems (more complex than the HO or the free particle) are submitted to the action of the ZPF (or ZPF plus Planckian) background. The most well-known example of that failure in SED was the hydrogen atom. By the late 1970s it was quite clear that the method most researchers were using to apply SED to the hydrogen atom would result in spontaneous ionization. The crisis that this and other examples of detailed energy balance failure created, e.g., the rigid rotator of Boyer, convinced many researches that either SED altogether had to be abandoned or else, quoting the authors "if SED in its present form is indeed a first step in the right direction, *further steps* are still wanting" (emphasis added).

A selection of these further steps is what constitutes Part III: Coda. In the first two chapters, namely Chaps 10 and 11, de la Peña and Cetto advance their own theory that they have appropriately called "linear SED," to distinguish it from the conventional SED theory. Linear SED has a number of innovating but unproven physical assumptions that the authors clearly identify. They present suggestive arguments for these assumptions to hold true. Although the theory amazingly leads to a close agreement with most of the physical predictions of QM and nonrelativistic QED, the physical assumptions are ones that several SED researchers may be unwilling to accept, certainly at least without considerable more support. Similarly, but for different reasons, traditional quantum theorists will also be undoubtedly troubled by linear SED. Fortunately, the reader is openly warned of the preliminary nature of the work in this last part. At various points the authors present fair and detailed critical evaluations of their work.

The key component of linear SED is the assumption that when the ZPF is in the presence of a material system, and consequently its modes are modified, then certain correlations among several mode components are established that preclude the components' stochastic independence. The ensuing couplings manifest themselves in simple additive constraint relationship among the corresponding random phases. The calculational procedure has furthermore included an averaging over neighboring wavenumbers, called k-averaging, that on physical grounds is based on the fact that radiative dissipation implies a broadening of the response that allows one to group modes responding in a narrow range of frequencies as a single entity. By means of these artifices, stochasticity disappears for certain discrete sets of frequencies that correspond to the quantum ones and that are the only ones at which the system can actually be found because they are the only ones yielding stability between the energizing due to the induced ZPF fluctuations and the corresponding radiative dissipation (i.e., for which there is detailed balancing).

A related highlight is the discussion in Chap 12 on the wave properties of matter where the authors present what will be to many people very tempting but nevertheless still only suggestive preliminary developments. Following in part ideas of A. F. Kracklauer, the authors develop an argument for the reconstruction of the de Broglie wavepacket for a moving electron as due to Zitterbewegung (i.e., an argument that the classical electron preferentially responds to the ZPF at the Compton frequency).

Next in Part III comes a chapter (Chap. 13) dedicated to stochastic optics. This is a theory, developed by Marshall and Emilio Santos (Santander, Spain) plus a few occasional collaborators, that represents an SED counterpart to quantum optics. Its most interesting byproduct probably is a fresh nonquantum approach to the Bell inequalities, particularly to the detailed analysis of the nonlocality and nonseparability experiments by Aspect, Rauch, and their numerous collaborators. It is argued that those experiments have not given conclusive results in order to rule out contextual hidden variable theories (the class to which SED belongs). Finally, Chap. 14 ends the book with the authors' outlook for the perspectives and connections of the theories they described in the book.

This book is quite amazing in terms of its wealth of references to previous related work in SED, which should be extremely helpful to researchers in SED. As a helpful aid, next to each reference in the very extensive bibliography at the end of the book, the chapter is indicated in *The Quantum Dice* where the reference was cited. Also, the book's index contains a very thorough listing by page of both subject as well as citations of a wide spectrum of SED related work by researchers. Consequently, even though many researchers will undoubtedly differ with regard to opinions and perspectives of the authors, this book will serve as a useful tool for all researchers and students of SED and related theories. In addition, many well explained and thorough discussions in the book will be very useful for the discerning readers.

Thus, a fair amount of material in this book will be welcomed by researchers in SED in terms of its coverage, description, and references. However, there is also a fair bit of more preliminary material mainly found in the Coda (Part III) that other researchers will find varying levels of discomfort and disagreement with, both for some simple discussions, as well as the broader perspectives and entensions to SED and its relationship and possible bridges to QM and QED.

Both experts in SED and newcomers to SED, who do not mind surveying preliminary ideas and extensions, yet who are keenly interested in reasonable alternatives to the conventional ideas of QM, will surely find this book of interest. In places the authors do an excellent job of summarizing the present limitations of the work done to date in SED. We describe the reading as enjoyable in general. All in all, this book is a must for any conscientious student of SED.

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