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Book Review

Quantum Chaos—An Introduction. Hans-Jürgen Stöckmann. Cambridge University Press, Cambridge, United Kingdom, 1999, xi + 368 pp., $85.00 (hardcover). ISBN 0-521-59284-4.

Quantum chaos is a subject which touches on many areas of physics. Because of its breadth, no single author has yet attempted to bring a comprehensive treatment of this exciting field under one roof, until now. "Quantum Chaos—An Introduction" by Hans-Jürgen Stöckmann is a wonderful and useful compendium of results which will be appreciated by both theorists and experimentalists working in this field. The author is uniquely qualified to write this book, having pioneered the field of wave chaotic microwave billiards. Many of the clearest manifestations of quantum chaos have been demonstrated through these microwave billiards experiments, much of them capably performed by the author's group.

The quantum mechanics of classically chaotic systems is the purview of quantum chaos. The term quantum chaos is a bit of a misnomer because the traditional definition of classical chaos, in terms of perfectly defined trajectories and extreme sensitivity to initial conditions, cannot be employed in quantum mechanical systems because of the uncertainty principle. Hence the manifestations of classical chaos on their quantum mechanical counterparts can sometimes be subtle. Stöckmann does a masterful job demonstrating many of the phenomena of quantum chaos through classical experimental analogs. The early presentation of Chladni figures on vibrating plates, water surface waves and ultrasonic waves in cavities, helps to bring the subject to life and shows the generality of the concepts underlying quantum chaos.

This book provides a breath of fresh air in the stratospheric field of quantum chaos where theory has traditionally dominated. It uses experimental results and numerical simulations to introduce both the most famous and the most arcane aspects of quantum chaos. The introductory chapters are an overview of the field illustrated with concrete experimental and numerical results and clear discussion of the significant manifestations

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of chaos evident in the data. These chapters alone serves as an excellent and comprehensive guide to the field of quantum chaos. This appeal to experiment to build the theory of quantum chaos is the book's greatest strength.

The microwave billiards experiments are used repeatedly throughout the text to illustrate the results of theory. As the author states, "probably there is no essential aspect of quantum chaos which cannot be found in chaotic billiards." In the process of using these wonderfully illustrative examples, one finds the most thorough and comprehensive discussion of microwave billiards in the literature.

Although firmly grounded in experiment, the author also treats many of the important theoretical results which form the foundation of quantum chaos. Stöckmann does a great service by explaining why the kicked rotator is such a favorite of theorists, and why it pertains so well to many experiments. This volume also contains one of the most readable introductions to random matrix theory available anywhere. The clear presentation of the many spectral statistics predictions of random matrix theory is also appreciated. The book also contains a very cogent account of supersymmetry theory and shows how its power can be used to calculate the ever-present ensemble averages in the theory of quantum chaos.

The intriguing result that quantization of classically chaotic time-dependent systems can lead to suppression of chaotic behavior is treated in one chapter. This phenomenon of dynamical localization is discussed in detail and then illustrated with the remarkable results of the ionization of hydrogen. An important emerging area of quantum chaos research is in the properties of scattering, or open, systems. Here again, the results are well illustrated with examples of eigenfunction fluctuations in microwave billiards and conductance fluctuations in quantum dots.

Quantum chaos in semi-classical systems has been an important theme of research. Here the influence of unstable periodic orbits has had a clear impact on theoretical treatments of these systems. The derivation of the Gutzwiller trace formula is presented and applied to several problems. The effects of periodic orbits on the structure of quantum chaotic eigenfunctions, known as scarring, is also discussed.

Quantum chaos touches upon many areas of physics, making this book is of interest to a wide variety of physicists. Nuclear Physics was the spawning ground for quantum chaos and harbors the classic results on level-spacing and eigenfunction statistics. Atomic physics provides examples of chaotic behavior of the hydrogen atom in strong magnetic fields and of dynamical localization of atoms in traps, a topic of great current interest. Much contemporary interest in quantum chaos is in condensed matter physics where fascinating examples of chaos abound. These include Anderson localization of electrons in disordered potentials, universal conductance fluctuations of mesoscopic systems, the properties of two-dimensional quantum dots, quantum corrals, and quantum well billiards. In fact the results of quantum chaos apply to almost all classical wave phenomena, including vibrational modes of plates, water waves in confined geometries, etc.

Although many of the derivations of landmark theoretical results presented in this book are basically recapitulations of work presented in other papers, they are put into context and crosslinked with other results in the field very elegantly. After reading this book one will have a much deeper understanding and appreciation for the field of quantum chaos.

This is a unique book which brings together many aspects of quantum chaos scattered over dozens of review articles and papers. The field is synthesized and presented to the reader in a very logical and readable form. The book also provides background for those new to the field so that they can appreciate all of the contemporary work, both theoretical and experimental. The reader is expected to have a good working knowledge of quantum mechanics. Having been derived from lectures for a course of quantum chaos, the book occasionally tests the reader's stamina with detailed derivations of certain landmark results. Despite its somewhat pedantic nature, I highly recommend this book to all who have an interest in quantum chaos.

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