

studied are simple computational networks having layered structures. One can prove that such a machine can compute any continuous function of its input variables with just one layer of simple computational units between input and output. So such studies have had quite general implications.

The unique contribution that statistical physicists were able to make to this work was, not surprisingly, the calculation of average properties in the “thermodynamic limit” in which both the size of the network and the number of examples are taken to infinity. This calculation complemented nicely a lot of other analyses that focused mostly on worst-case scenarios, often of finite networks.

To obtain generic knowledge one has to consider random distributions of examples, which places the problem in the realm of disordered system theory (as originally developed for alloys and polymers). Elizabeth Gardner and her coworker Bernard Derrida pioneered the application to these networks of methods from spin glass theory and thus opened the door to hundreds of subsequent investigations that have provided much new insight into learning systems. The models, methods, and results are the focus of Engel and Van den Broeck’s book.

The book starts by orienting the nonexpert reader to the basic concepts in the field and then illustrates those concepts for the simplest kind of machine, the perceptron—a machine that simply computes a weighted sum of its inputs and gives a 1 or 0 output, depending on whether the sum is above or below a threshold. The authors then further develop the statistical mechanical framework, including the “replica” methods from spin glass theory, and the reader is given simple yet nontrivial examples of phase transitions. Subsequent chapters treat topics such as data clustering, the statistical dynamics of learning, the multifractal structure of the parameter space in a problem, and more complex networks. There is also a nice chapter relating the results obtained by these methods to those found by other techniques.

Given the highly technical nature of the calculations, the presentation is miraculously clear, even elegant. Although I have worked on these problems myself, I found, in reading the chapters, that I kept getting new insights. And for someone interested in applying these methods to other problems (perhaps joining in the current work on error-correcting codes and hard optimization problems, which are sketched in the final chapter), I can’t

think of a better place to learn the techniques. In fact, for readers with all levels of interest, I highly recommend this book as a way to learn what statistical mechanics can say about an important basic problem.

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Quantum Optics in Phase Space

▶ Wolfgang P. Schleich
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Travel literature has its own vague rules and guidelines, flexible enough to include books that are little more than checklists of recommended museums, sights, and restaurants, along with careful descriptions of foreign climates both cultural and meteorological. They might even include intensely personal diaries that reveal the thinking of the writer as much as they reveal the geographic locale. Physicists can recognize analogs of all these types on their bookshelves, but the regions under review are not foreign countries but some part of physics or another.

Wolfgang P. Schleich’s *Quantum Optics in Phase Space* is a new contribution to physics travel literature, and it deserves praise as a guidebook. The book, suitable for almost any physicist contemplating an expedition through the quantum jungle, is timely, published at the same time that many of the jungle’s mysterious elements are being charted by physicists using the techniques of quantum optics. In effect, the book shows how the classical insights associated with wavepackets and phase space can be exploited to tame many of the jungle’s nonclassical creatures.

Schleich’s guided expedition begins in chapter 1 with an overview of the territory to come—something like a slide show on the evening before leaving base camp: highlights and snapshots (in no particular order) of some of the foundational ingredients and keynote topics of modern quantum optics. Schleich’s overview covers two-level atoms, single modes of radiation, antibunching, squeezing, cavity quantum electrodynamics and one-atom masing, de Broglie optics, fluorescence line-splitting, and entanglement. Schleich has selected these snapshots well, so an accurate impression is quickly obtained of the

several ways in which quantum optics bridges the quantum–classical border. One easily gets the impression, I think accurately, that quantum phenomena are both highly puzzling and best illuminated by quantum optical investigations in the vicinity of this not-so-well-defined border.

The tour continues with a chapter called simply Ante, basically another slide show and an important one for readers who want a quick refresher course on the apparatus of quantum theory, which they will encounter in later chapters. With admirable concision, Schleich defines and illustrates key elements of representation theory, the density matrix and quantum averages, the quantum harmonic oscillator, the concept of interaction Hamiltonian, and different approaches to time evolution. While doing so, he finds it easy to hand out an array of formulas that will be useful in what follows.

Schleich explains that the main journey will start with a visualization of quantum states using the Wigner function, which introduces easily the notions of state squeezing and state reconstruction. A review of the WKB (Wentzel-Kramers-Brillouin) method is then connected to the Berry phase, leading the reader to interference in phase space and the dynamical behavior of wavepackets. Here Schleich takes his time, profitably deconstructing the character of revivals and fractional revivals as an illustration of the always fruitful procedure of time-scale analysis.

Generalizations of the Wigner function, particularly the quantum phase space machinery of Roy Glauber and George Sudarshan, are important in quantum optics in connection with photon detection, so several chapters are devoted to aspects of field quantization and photon states (Fock, coherent, Schrödinger-cat, and so on). These are followed by discussions of fundamental photonic devices and techniques, including beam splitters, homodyne detection, interferometers, and photon-count statistics.

Field quantization is also needed for examination of the quantized atom–field interaction, and Schleich commendably includes such topics as the gauge principle and the validity of the dipole approximation, topics that are frequently dodged for convenience. Introduction of the two-level atom artifice is justified, and one is led naturally to one of the central themes of quantum optics, cavity QED, where one encounters the interaction between light and matter in the context of the famous Jaynes–Cummings

model (the spin-boson model made exactly soluble in rotating wave approximation). Schleich uses the designation Jaynes-Cummings-Paul model to alert readers to the less well-known work of Harry Paul. Exact dynamical solutions and many examples are given, including instructive ones that include atom-field entanglement and its use in state preparation. Three chapters then exploit these developments to examine interactions that include the quantum effects of atomic motion. In this context, Schleich treats atoms and ions in traps, in free space, and in optical lattices.

The concluding chapter uses Wigner functions and phase space visualization to examine aspects of atom optics, returning the book to its opening theme and completing our guided tour of the quantum jungle. Except that it's not the end of the book. There are fully 90 pages of side thoughts, derivations, and overflow discussions in 17 appendices that include, for example, one devoted to the square root of the Dirac delta function. These would make a small reference work by themselves, and they show in another way Schleich's sensitive attention to detail, for which most students will be grateful. The same care is also displayed in the annotated citations, a score or more at the end of nearly every chapter. There are also homework-style problems, for the dedicated reader. Is there anything for the student that should be here that is not? I doubt it. My strong recommendation is to sign on and enjoy the tour.

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Molecular Engineering of Nanosystems

▶ Edward A. Rietman
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Nanotechnology is an explosively growing field. K. Eric Drexler's book *Engines of Creation* (Fourth Estate, 1990) showed how creative molecular engineers might be able to make a wide variety of nanoscale molecular machinery. While Drexler's book opened eyes to the opportunities in molecular-scale engineering, there has been a need for a book dealing with the more rigorous aspects of chemistry and physics needed to take this field to fruition.

Molecular Engineering of Nanosystems by Edward A. Rietman takes the

discussion one step further by providing an intuitive, scientific framework for understanding nanoscale systems. The book is part of Springer's Biological Physics series, but the preface suggests the targeted audience might be computer scientists. Rietman has organized the book around his precept that "solution-phase chemistry and protein engineering will bootstrap us into the first phase of nanotechnology." This seems like quite a reasonable starting point; a tremendous number of biological processes involve controlling molecular architecture on nanometer length scales, so it makes sense to look

to natural systems as a guide for synthetic nanosystems engineering.

The book starts with a review of some of the important concepts from solution-phase chemistry. It then moves on to discuss the dynamics that control intermolecular interactions, the formation of molecular systems, and, ultimately, protein and DNA engineering.

The order of presentation, generally moving from fundamental science toward complex systems, seems reasonable. The placement of material within the individual chapters occasionally seems less well organized. A section of about one-and-a-quarter