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Physical Models of Living Systems

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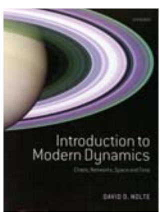
A bold step toward invigorating the physics curriculum

Introduction to Modern Dynamics
Chaos, Networks, Space and Time

David D. Nolte
Oxford U. Press, 2015. $110.00
(448 pp.). ISBN 978-0-19-965703-2

Reviewed by David P. Feldman

In his book *Introduction to Modern Dynamics: Chaos, Networks, Space and Time*, David Nolte has set himself an ambitious task: to modernize and broaden the upper-level undergraduate dynamics course for physics majors. His text covers classical mechanics, special and general relativity, and a host of topics from nonlinear dynamics and complex systems. The unifying theme connecting those topics is a geometric approach to dynamics—studying the time evolution of trajectories through an abstract space such as a state space or a phase space.



Nolte covers a vast amount of material in just over 400 pages. The breadth of coverage, together with Nolte's succinct, straightforward prose, is a strength of the book. However, the book's breadth is also perhaps a limitation, because many topics are given only minimal coverage. The level of abstraction and mathematical sophistication is quite high—another feature that is both a strength and a potential limitation.

The book is divided into four parts. Part 1 (chapters 1–2) is a geometric overview of classical mechanics. Part 2 (chapters 3–5) is on nonlinear dynamics. In part 3 (chapters 6–8) each chapter examines a particular area of complex systems: neural dynamics and neural nets; evolutionary dynamics; and economic dynamics. And part 4 (chapters 9–11) returns to traditional physics topics in its survey of special and general relativity and their associated mathematical machinery. The text of each chapter is followed by 10 to 15 exercises, both analytic and computational. Matlab code for the exercises is provided on Nolte's webpage (http://works.bepress.com/ddnolte).

To me, the strength of Nolte's text is chapters 4 and 5, on network dynamics and synchronization, and the three chapters in part 3. Each of those five consecutive chapters serves as a primer for a particular aspect of dynamics or complex systems. I am not aware of any other text that includes a similar set of topics. The level of mathematics in those chapters remains high, but it strikes me as less forbidding than the level that appears in the earlier chapters. By necessity, the treatments in those five primers are brief; some topics receive just a cursory look. Nevertheless, I think the chapters could serve as effective entry points to the fields they discuss.

Nolte's writing is generally clear and concise; his presentation leaves room for instructors to add details, applications, and points of emphasis to suit their students' needs. I share the author's belief that complex systems and nonlinear dynamics deserve an earlier and more prominent role in the physics curriculum; such a reemphasis would introduce students early on to the excitement of current research and open-ended questions.

Moreover, work in complex systems and nonlinear dynamics involves the interplay of numerical investigation, rigorous mathematics, and clever analytic approximations—a combination that, I believe, is at the heart of physics. Incorporating nonlinear dynamics and complex systems into undergraduate physics coursework will likely be beneficial because the excitement and applicability of the field will draw students in and prepare them to work effectively both in physics and in interdisciplinary collaborations.

Has Nolte succeeded in writing a text that could work for a modern upper-level undergraduate mechanics course emphasizing chaos and complex systems? My thoughts on this question are mixed. I don't think *Introduction to Modern Dynamics* could be a direct replacement for conventional texts: The level of abstraction in parts 1 and 4 is probably too high for most undergraduates. Some topics are covered briefly early in the book, like the Frenet–Serret formulas and the Einstein summation convention. Also, rigid-body rotation and central-force motion are each covered in short, roughly 10-page sections; in Stephen Thornton and Jerry Marion's well-used *Classical Dynamics of Particles and Systems* (Brooks/Cole, 2007), each is treated in 40- to 50-page chapters. I think chapter 3, on dynamical systems, will also be tough sledding for readers who have not had an initial encounter with dynamics, especially bifurcations. However, more seasoned undergraduates or beginning graduate students would likely be ready for the geometric and abstract approach Nolte takes.

Introduction to Modern Dynamics strikes me as two books in one: a beginning graduate-level modern analytical-mechanics text emphasizing geometric techniques and a survey for advanced undergraduates of some current topics in the dynamics of complex systems. The bifurcation is an understandable consequence of the need to accommodate the perhaps outdated dictates of the traditional advanced undergraduate mechanics course. Nolte's book is a bold attempt toward updating and energizing the physics curriculum. It may not fully achieve that goal, but it is a significant and noteworthy effort. I encourage instructors to give it a look and see if there is a place for it in their teaching.

David Feldman is a professor of physics and mathematics at the College of the Atlantic in Bar Harbor, Maine. He is the author of *Chaos and Fractals: An Elementary Introduction* (Oxford University Press, 2012).

Physical Models of Living Systems

Philip Nelson
W. H. Freeman, 2015. $134.99
(384 pp.). ISBN 978-1-4641-4029-7

"Learn from science that you must doubt the experts." That famous Richard Feynman quote is Philip Nelson's opening invitation to readers of *Physical Models of Living Systems*, a well-written and carefully structured text that's particularly compelling for its smooth integration of biological experiments, physical models, and computational exercises. Readers who complete the text will be well equipped with the

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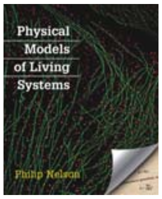
computational and mathematical skills needed for a quantitative understanding of a range of biological systems and thus be enabled to "doubt the experts" and independently evaluate scientific claims.



Nelson is widely recognized for his excellence as a teacher: He is a 2009 recipient of the Biophysical Society's Emily M. Gray Award for his contributions to innovative teaching of biophysics. *Physical Models of Living Systems* is different from his previous book, *Biological Physics: Energy, Information, Life* (W. H. Freeman, 2003; reviewed in PHYSICS TODAY, November 2004, page 63), and from other biophysics textbooks in that it does not attempt to cover the entire field. Instead, its aim is to teach the importance of using physical models to gain insight into biological phenomena at various levels of complexity. The book achieves that goal by appealing to a few compelling biological problems—for example, HIV dynamics, molecular motors, and biological oscillators.

The book is organized into 3 parts and 11 chapters, plus an epilogue and 3 appendices. Each chapter begins with an overview of the goals and with chapter-specific biological and physical focus questions. Interspersed throughout are several tasks designed to increase understanding and proficiency through self-testing. Particularly helpful are the figures that Nelson reprises from previous sections; their reappearance in the margins makes for easy reference. For more advanced students, the author provides supplemental in-depth details and exercises. Each chapter concludes with a big-picture summary, key formulas, further reading, and numerous analytical and computational practice exercises.

The first two chapters make up part 1 of the book, "First Steps." It is a 23-page introduction to the relationship between physics and biology and to basic concepts of fitting and modeling experimental data. Nelson uses HIV infection as a captivating biomedical problem to spark the reader's interest and illustrate the power of mathematical modeling.

Part 2, "Randomness in Biology" (chapters 3–7), covers the fundamentals of probability theory: randomness, discrete and continuous probability distributions, maximum likelihood, parameter estimation, and Poisson processes. Nelson keeps the reader engaged by intermixing the core concepts and necessary mathematics and terminology with lively examples that illustrate the power of statistical analysis. I particularly enjoyed his skillful demonstration of the value of computer simulations in the context of the Luria–Delbrück experiment, which established the occurrence of bacterial genetic mutation in the absence of selection.

In part 3, "Control in Cells" (chapters 8–11), the author builds on the skills presented in part 2 by diving deep into the cell's inner dynamics and covering important problems of control circuits—for example, gene expression, enzyme dynamics, genetic switches, and biological oscillators. Because the complex biological details may seem overwhelming, Nelson first introduces biological control systems through familiar physical systems: for example, a centrifugal governor introduces negative feedback control and a mechanical toggle sets the stage for biological toggle switches. He then applies the concepts to such concrete biological examples as repressor cooperativity, the lambda and lac switches, and genetic oscillators.

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Physical Models of Living Systems is an entertaining and engaging textbook that hits a perfect balance between biological experiments, physical models, and computational approaches. Thanks to Nelson's skillful writing and the excellent accompanying online resources, this book will appeal to a broad audience and teach even a beginner how to solve problems numerically. It could serve as the primary text for an introductory course in quantitative biology or as enriching supplemental reading material for undergraduate or graduate biophysics or bioengineering courses.

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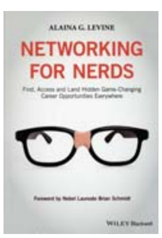
Networking for Nerds
Find, Access and Land Hidden Game-Changing Career Opportunities Everywhere

Alaina G. Levine
Wiley, 2015. $29.95 paper (248 pp.).
ISBN 978-1-118-66358-5

I have always refused, on principle, to read books from the *For Dummies* series. Although I find "nerd" less insulting than "dummy," I had similar reservations when I saw the title of Alaina Levine's new book, *Networking for Nerds: Find, Access and Land Hidden Game-Changing Career Opportunities Everywhere*.

Levine is founder and president of Quantum Success Solutions, a public-speaking and leadership-training business. She has received acclamation for providing career-skills training to scientists through articles, webinars, and other activities, including her occasional blog posts for PHYSICS TODAY's website. The aim of her book—to teach students and professionals in science and related fields the networking skills needed to become leaders—is something I have long promoted as an adviser, and now director, of the Society of Physics Students. Recently Wes Watson, an SPS chapter officer at Sonoma State University, told me that "SPS turns nerds into leaders." So I put aside my reservations and decided to see what *Networking for Nerds* had to offer.



Many scientists might ask why they should take the time to read a book on professional networking. Levine addresses that question in chapter 1; astrophysicist and Nobel laureate Brian Schmidt also addresses it in the foreword. Essentially, they both state that professional networking is critical for scientific advancements because it leads to collaborations and the exchange of ideas. Levine also discusses the "Hidden Platter of Opportunities," a phrase she trademarked, which refers to the jobs and opportunities that come through a personal connection. And in making a distinction between valuable scientific networking available to all and unsavory backroom dealings, she sets the tone for the remainder of the book.

At just over 200 pages, *Networking for Nerds* is a relatively quick read, full of great advice. Replete with personal anecdotes, it covers a wide variety of topics, from dinner etiquette to critical tools for making the most of scientific conferences and social media. It also highlights the importance of learning to deal with failure, something all young scientists need to understand. For those of us who like to get to the highlights quickly, the book offers three useful features: bulleted textbook-style "Chapter Takeaways" summarizing key points; numerous text boxes containing tips; and an easily consumed main text, broken up into bulleted lists and small, digestible chunks.

It is difficult to determine which ideas in the book are original. Some of the topics have long been discussed, and many other articles, books, and websites treat the subject. However, Levine's is the most complete single-volume coverage of networking for science students and professionals that I have come across, and her presentation on several topics is fresh and useful.

Physics students at all levels would benefit greatly from the lessons in this book. For example, during my frequent participation in the undergraduate sessions at scientific meetings, I have observed that students tend to interact primarily with people from their own institutions. They are missing a great opportunity; I encourage them to avoid doing that, as does *Networking for Nerds*.

All scientists, not just students, are likely to pick up several good tips from this book, especially on such contemporary topics as using social media for serious professional activities. Overall, Levine provides valuable advice on how to build and take advantage of your professional network—whether or not you like to be called a nerd.

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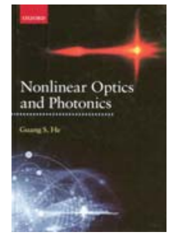
Nonlinear Optics and Photonics

Guang S. He
Oxford U. Press, 2015. $89.95
(631 pp.). ISBN 978-0-19-870276-4

Several generations of physics and engineering students no doubt recall with affection (or dread) John David Jackson's well-known text *Classical Electrodynamics*, whose third and most recent edition was published by Wiley in 1998. It offered graduate students their first rigorous introduction to electromagnetic waves and optics but mostly stuck to linear physics.



One of the first texts to go beyond linear optics was Robert Boyd's now-classic *Nonlinear Optics* (Academic Press, 1992). Its fresh perspective coupled with a succinct and clear stress on the fundamentals made the subject matter accessible to graduate students. However, it omitted such important topics as the response function of materials. The third edition (Academic Press, 2008) addressed the early shortcomings and now stands as the most balanced and clearly presented among the many nonlinear optics (NLO) texts.

A recent addition to that list is Guang He's *Nonlinear Optics and Photonics*. The new tome by He, a senior research scientist at the Institute for Lasers, Photonics, and Biophotonics at the University at Buffalo, draws on his extensive experience. The first 10 chapters are dedicated to the fundamentals, and each chapter ends with a set of problems. The rest of the book covers a sampling of advanced topics and applications, but does not provide corresponding problems. As such, we are presented with a hybrid: part textbook, part reference.

The range of phenomena that is covered by the NLO umbrella is so wide that no single volume can cover every topic. In large part, then, the distinction between NLO books is in the choice of topics emphasized, the target audience, and the clarity of presentation. *Nonlinear Optics and Photonics* stands out for the breadth of topics, and the many useful illustrations, that go beyond the normal fare. For example, chapter 16 covers various aspects of fast and slow light. The author begins by providing a careful definition of phase velocity and group velocity. He also describes how a wavepacket is affected in gain media,

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