historically interesting data. For example, a telling series of three resonance curves, for beams of molecular hydrogen and deuterium, shows the progression from Ramsey's first, rather noisy signals to later beautifully resolved resonances of I. I. Rabi's group from which the electron's quadrupole moment was determined. The quadrupole moment showed that the force between protons and neutrons was not purely central but had a substantial, spin-dependent tensor component.

Each chapter is self-contained and is just the right length for 5 or 10 minutes of light reading before bedtime. Equations are limited to such simple examples as Balmer's formula for the wavelengths of the hydrogen spectra, and Dirac's deceptively simple version of the Schrödinger equation.

A few more diagrams of basic experimental arrangements would have been helpful to the nonexpert reader. For example, the book has many discussions of spectral lines, but no diagram of the refraction of light into its constituent colors, something that even Isaac Newton considered essential for his celebrated *Opticks*.

Although Rigden gives credit to experimentalists, he reserves his most reverent passages for theorist heroes. His emphasis on theory causes some eccentricities in the historical perspective. For example, there are three references to "spin" in the index, two to the Dirac theory of the electron and one to the respective integer and half-integer spins of bosons and fermions. Samuel Goudsmit's name does not appear in the index. Goudsmit's noted colleague George Uhlenbeck is mentioned in a single sentence: " 'The Schrödinger theory came as a great relief,' said George Uhlenbeck, the codiscoverer of the electron spin" (p. 81).

Although precise studies of the hydrogen atom have had enormous and indisputable importance in the development of physics, one might question the primacy that Rigden assigns to hydrogen. Studies of the alkali-metal atoms have had comparable importance in the development of atomic clocks and in the discovery of the Fraunhofer D lines, electron spins, and Bose–Einstein condensation. Silicon, which launched salient developments in condensed matter physics, underpins our information age. Rigden makes little mention of accelerators, which have been essential for our understanding of the subatomic world. True to its title, the book keeps hydrogen as the guiding theme.

I intend to keep *Hydrogen: The Essential Element* close at hand as I prepare lectures on quantum mechanics. The personalities of scientists who have revealed the rich physics of the hydrogen atom shine through clearly, and will help to capture the imagination of new generations of young scientists.

**William Happer**
*Princeton University*
*Princeton, New Jersey*

## Higher-Order Numerical Methods for Transient Wave Equations

Gary C. Cohen
*Springer–Verlag, New York, 2002. $69.95 (348 pp.).*
*ISBN 3-540-41598-X*

Problems involving wave propagation occur in many disciplines, including acoustics, electromagnetics, geophysics, elasticity, and fluid dynamics. Long ago, in *Methods for the Approximation of Time Dependent Problems* (GARP Publications Series, No. 10, 1973), Heinz-Otto Kreiss and Joseph Oliger advocated the use of high-order discretization for such problems, especially for long-time integration. Kreiss and Oliger argued that the number of grid points needed in a unit interval of wavelength depends on the time interval of integration: The higher the formal order of the discretization scheme, the weaker is its dependence on the time interval. To my knowledge, *Higher-Order Numerical Methods for Transient Wave Equations*, by Gary C. Cohen, is the first book to address specifically the use of high-order discretizations in the time domain to solve wave equations. Traditionally, the engineering community solved such problems in the frequency domain, but recently have tended to abandon that harmonic approach amid an increase of interest in complex pulselike sources containing a large range of frequencies. Cohen, a researcher at the French National Institute for Research in Computer Science and Control (INRIA), has been working on this topic for more than 15 years.

The book is divided into three parts. Part 1 (chapters 1–3) presents the governing equations for acoustics, electromagnetism, and material elasticity. This part provides a useful overview of functional spaces and introduces the appropriate Sobolev spaces. Chapter 3 presents plane-wave solutions to Maxwell's equations and to the elastics system. This chapter is useful, but touches only briefly on the major issue of boundary conditions.

Part 2 of the book (chapters 4–10) deals with construction of second- and fourth-order standard finite-difference schemes for both space and time. The material is fairly standard except for the modified-equation approach introduced in the mid-1980s, which evolved to uniform fourth-order spatiotemporal schemes. The notation in chapter 4 is perhaps unnecessarily heavy: It renders cryptic and hard-to-recognize even simple Taylor expansions that should be familiar to undergraduate students! I also expected to find more on compact (implicit) schemes and treatment of stability issues associated with boundary conditions—including reduction of the order of accuracy at the boundaries. However, the book does not contain such material. A one-line reference to spectral methods dismisses them as ". . . very difficult to implement . . ."(p. 57). Other topics in part 2 include stability of the discrete schemes (including energy techniques), numerical dispersion and anisotropy, reflection-transmission analysis, and construction of schemes in heterogeneous media. The description is quite rigorous but easy to follow, and the remarks at the end of each section are very useful.

Part 3 (chapters 11–14) presents various finite-element formulations and contains by far the most interesting material in the book. The key development in the use of finite elements in this context is the mass-lumping concept. In mass lumping, one constructs a diagonal mass matrix in a way that does not impair the formal accuracy of the finite-element discretization. The author presents mass lumping in detail, although his account of its history is somewhat erroneous. The use of Gauss–Lobatto points was introduced at MIT in the early 1980s in the context of spectral elements. In talking about the MIT contribution, the author refers to spectral elements as any finite elements of order higher than three and thus seems to contradict the vast majority of literature on the subject. The quadrilateral/hexahedral elements favored by the author have good approximation properties. However, the author seems unaware that tensor-product bases developed in the past 10 years make triangular/tetrahedral elements competitive with—perhaps even better than—quadrilateral/hexahedral ones. Therefore, the text's discussion entitled "Tetrahedra or Hexahedra?" is not justified.

The section in Part 3 on mixed formulations, which is quite good, extends the classical finite-difference Yee scheme to finite elements. For transient wave equations, Cohen's extension of the Yee scheme is more efficient and accurate than the classical Lagrange finite elements. The improvements result from Cohen's use of a new class of elements, called edge elements, to ensure continuity at the elemental interfaces of the tangential components of the finite-element basis functions.

The book's last chapter (chapter 14), devoted to outflow boundary conditions, analyzes in detail the method of perfectly matched layers (PML). The chapter mentions other methods, but not in enough detail for the unfamiliar reader to compare their merits with those of PML.

Cohen's book should be useful, especially to new researchers, and could even be a reference in a course. I would not recommend it as a textbook, because it has no problem sets, is not self-contained, and does not treat other useful topics such as compact schemes, explicit and implicit filtering, and discontinuous Galerkin methods. However, I recommend the book for its clear and cogent coverage of the material selected by its author.

**George Em Karniadakis**
*Brown University*
*Providence, Rhode Island*

## Nexus: Small Worlds and the Groundbreaking Science of Networks

Mark Buchanan
*W. W. Norton, New York, 2002. $25.95 (235 pp.). ISBN 0-393-04153-0*

## Linked: The New Science of Networks

Albert-László Barabási
*Perseus, Cambridge, Mass., 2002. $26.00 (280 pp.). ISBN 0-7382-0667-9*

Complex networks pervade our world. A few familiar examples include the metabolic network in a tiny cell, neural networks in the brain, networks of friends and acquaintances in a society, collaboration networks in scientific communities, ecological networks, economic networks of international companies trading worldwide, the Internet, and the World Wide Web. Finding the laws that govern the formation, evolution, and function of complex networks has been a major concern in recent research.

*Nexus*, by Mark Buchanan, and *Linked*, by Albert-László Barabási, tell the fascinating story of physicists' and mathematicians' search for the laws of complex networks. Both books, clearly and elegantly written for a lay audience, make three main points. First, the reductionistic approach that dominated science in the last century will not help us to understand complex networks. The specific nature of the individual network elements is irrelevant to understanding the collective behavior of the network in much the same way as the detailed properties of a water molecule are irrelevant to understanding turbulence. As Barabási put it in the first chapter of *Linked*, ". . . here is a secret that never makes the headlines: We have taken apart the universe and have no idea how to put it back together."

Second, networks in nature do not have the kind of homogeneous random architectures that the eminent mathematicians Paul Erdös and Alfred Rényi analyzed in the mid-20th century. On the contrary, real networks such as the Web or the Internet, which were assembled through the collective action of millions of individuals acting separately and randomly, are far from random or homogeneous. (This is one reason they are called complex networks.) Using interesting and well documented examples, Buchanan and Barabási show that departure from randomness applies not only to informatics networks, but also to cellular, social, and ecological networks.

The third main point in *Nexus* and *Linked* is that a common architecture may be shared by such diverse systems as the metabolic network inside the cell, the Hollywood movie-actor network, and the network of sexual contacts in a human society.

Although *Nexus* and *Linked* overlap in many respects, on this third point they diverge in their emphasis.

Buchanan's *Nexus* emphasizes the small-world architecture, in which network elements connect mostly to their near neighbors and only infrequently to distant elements. The small-world architecture in a social network was made evident by the Harvard psychologist Stanley Milgram in 1967 and is popularly known as "six degrees of separation": Any two people in the world are separated, on average, by only six acquaintances.

On the other hand, Barabási's *Linked* emphasizes another architecture called scale-free topology, characterized by inhomogeneous connections.


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