plained. On some points, such as the lambda lemma or the differentiability of the stable manifold, where any proof is necessarily rather technical, the authors provide references in which the arguments can be found. Although the widespread interest in nonlinear dynamics has produced a number of books on the subject, very few offer this level of mathematical detail and rigor packaged within a genuinely introductory discussion.

The organization of the material has several notable characteristics:

Overall, the subject is presented in what I would call reverse order: The opening chapters treat chaos in maps, fractal sets and various bifurcations (such as crises) that arise in the examples; in later chapters, we find flows in one- and two-dimensional phase spaces and a description of the elementary bifurcations from fixed points. I would guess that this order might be hard on some students, but I have not tried it in my own teaching. It is undeniably economical, if you want to get to the sexy topics fast.

While their main focus is on the mathematics and the study of various model equations, the authors convey the relevance to real experiments through 12 "lab visits" that appear as chapter appendices. These are brief sketches of the appearance of the dynamical phenomena when seen in the flesh, with examples chosen from chemistry, physics and biology. A second set of chapter appendices, written in the form of extended homework exercises, expand on the theoretical development of each chapter. These "challenges" include the proof of Sharkovskii's theorem, the application of shadowing to justify numerical computation of chaotic trajectories and the analysis of synchronization between coupled chaotic systems.

In addition to covering standard topics, also found in many other texts, there are quite readable introductions to a number of advanced topics. In the context of well-chosen examples, the authors describe Markov partitions, invariant measures and natural measure, shadowing, periodic orbit cascades and so-called Wada basins (whose fractal boundaries have a structure that is almost beyond belief). Many of these examples derive from the research of the authors. The book concludes with a chapter on phase-portrait reconstruction from experimental time series and a discussion of various embedding theorems.

The book omits some things that I like to include in an introductory graduate course. Surprisingly, the concept of structural stability is not developed. As a result, although the pages are filled with examples of bifurcations, the concept of bifurcation as a change in the topological equivalence class is never formulated. Similarly, Peixoto's theorem on two-dimensional flows is not stated. The discussion of elementary bifurcations for maps and vector fields omits center manifolds and normal forms entirely, so the reader cannot appreciate the full significance of the simple one- and two-dimensional examples. Hopf bifurcation in maps is not presented. The importance of homoclinic points is stressed, but Melnikov methods for detecting them are not mentioned. In a discussion of a damped driven pendulum, the main point of which is to introduce a return map with fractal basin boundaries, the authors miss an opportunity to explain how dimensional analysis allows a model to be simplified. Instead we are told that to obtain the dimensionless model, it is necessary to "use a pendulum of length $l = g$." How to achieve this feat is presumably an exercise for the reader!

I think the text should be quite useful for physics graduate courses and honors-level undergraduate courses, although it contains far more material than could be covered in a single term. By the same token, it is a serious introduction, with wider coverage of the subject than is readily available from any other single source.

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Classical Field Theory: Electromagnetism and Gravitation

Francis E. Low
Wiley, New York, 1997. 427 pp.
$59.95 hc ISBN 0-471-59551-9

The two classical fields found in nature, electromagnetism and gravitation, have much in common, but their differences are so great that there have been few attempts to treat both subjects in a single volume. Francis E. Low's *Classical Field Theory* succeeds in doing this in a manner that would make it useful in an introductory course at the graduate level. Overall, I feel that it is a welcome addition to the textbook literature, although, as detailed below, it also has some significant flaws and deficiencies.

The writing style throughout the book is clear, and I encountered very few errors of any kind. A good selection of problems is provided at the end of each chapter. However, there are virtually no "worked problems" in the text, and Low assumes a degree of sophistication for the reader that, in my opinion, is somewhat higher than could reasonably be expected of an average first-year graduate student in physics. Thus, I believe that many students would encounter some difficulties if the book were used as the main text in a course.

The first three-quarters of *Classical Field Theory* is devoted to classical electromagnetism. The level and style are comparable to those of the standard text by J. D. Jackson, *Classical Electrodynamics* (Wiley, second edition, 1975), but Low's book has a greater emphasis on purely theoretical issues and a very significant de-emphasis of applications. As examples of the former, a good general introduction is provided to both classical scattering theory and Lagrangian field theory. The reader will also get a good introduction to Fourier transform methods, which are extensively used throughout the book. In general, most of the mathematical and physical aspects of classical electromagnetism that play a direct role in modern theoretical particle physics are given good, comprehensive treatments in Low's book.

On the other hand, no treatment whatsoever is given of many topics in classical electrodynamics that play a key role in astrophysics, plasma physics and experimental physics. Some examples of these topics are synchrotron radiation, magnetohydrodynamics, wave guides and energy loss by charged particles passing through matter. Another significant deficiency is the absence of any discussion of eigenfunction expansion techniques for solving boundary value problems or obtaining Green's functions. Because of these omissions, it is difficult to see how this book could be used as a text for a course that is intended to serve a broad range of graduate students.

The last quarter of the book treats classical gravitation in a thoroughly ungeometrical manner, very similar in approach, level and style to Steven Weinberg's *Gravitation and Cosmology* (Wiley, 1972). However, unlike Weinberg's text, Low's does not progress beyond the mathematical formalism to the applications of general relativity to astrophysics and cosmology. Much of the underlying simplicity of the theory is obscured in the approach taken by Low, as illustrated in section 7.7, where it is shown that, at any point, the coordinate components of any metric always can be transformed to a pseudo-Euclidean form with vanishing first partial derivatives. As presented by Low, this result appears to be a consequence of a lengthy calculation involving a miraculous equality of the number of equations (namely 40) and unknowns (also 40) that must be solved to find the desired coordinate transformation. By contrast, from the geometrical point of view, the result is a direct consequence of the ability to construct a coordinate system based on geodesics passing through the given point.

In addition, there are a few flaws in Low's treatment of general relativity that are worthy of mention. First, Low's use of point particle sources is valid only in the context of linearized gravity; the fully nonlinear Einstein equation with point particle sources does not make mathematical sense. Second, no adequate warning is given to the reader of the highly gauge-dependent nature of the gravitational stress tensor. Finally, the claim in section 7.6 that dx^μ is a contravariant vector is in direct conflict with standard mathematical usage of that terminology. In fact, $\{dx^\mu\}$ is a basis of covariant vectors, with μ labeling the elements of this basis. The fact that the coordinate bases for two different coordinate systems are related by the same formula that applies for the transformation of the components of a contravariant vector does not make dx^μ a contravariant vector.

Despite these criticisms, I feel that Low's book provides a valuable introduction to electromagnetism and gravitation at the graduate level and will be of particular use to aspiring theoretical particle physicists.

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Yerkes Observatory, 1892–1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution

Donald E. Osterbrock
U. Chicago P., Chicago, 1997. 394 pp. $40.00 hc
ISBN 0-226-63945-2

Yerkes Observatory, located in southern Wisconsin, was founded exactly a century ago. From the beginning it was a world leader in what was called the "new astronomy," astrophysics, the application of spectroscopy and photography to the study of the physical processes of stars and interstellar gas. Donald Osterbrock's *Yerkes Observatory, 1892–1950*, however, deals only peripherally with the astronomy produced at Yerkes; rather, it is a detailed chronicle of the men, organizations, academic politics and finances that shaped the institution's checkered history over the tenure of its first three directors, George Ellery Hale, Edwin Frost and Otto Struve. Osterbrock, former Lick Observatory director and Yerkes astronomer (as a graduate student), has scoured major archives to piece together his detailed story.

Born almost simultaneously with its parent University of Chicago, Yerkes was headed first by Hale, an innovative astronomer and master fund-raiser even in his twenties. With money from the archetypal railroad tycoon Charles Yerkes and strong support from the university's first president, William Harper, Hale oversaw the first staff appointments and the installation of a 40-inch-diameter refracting telescope, then and now the largest of its type in the world. Hale soon realized, however, that the technology of large mirrors was such that the future of astronomy lay with reflectors and that, furthermore, these should be located on mountaintops with good weather. (One staff astronomer observed, "Yerkes is a pleasant and easygoing place where we sometimes see the stars.")

In 1904 Hale secured another large grant, this time from Andrew Carnegie, and set off to build a 60-inch reflector and found Mt. Wilson Observatory in California. This left Yerkes in the less skilled hands of genial Edwin Frost, who remained director for three decades (during the last of which he suffered complete blindness). Osterbrock describes the decline in the quality of the staff and research under Frost's management style (he calls it the "near death" of the institution). But there was one bright appointment, that of Otto Struve, White-Russian soldier and refugee and scion of an astronomical family, who joined the staff in 1921.

Although Struve had established himself as an extremely productive researcher, it was unexpected and controversial to name this "foreigner" a "boy director," at age 35, in 1932. Over the next two decades Struve, tightly partnered with university president Robert Hutchins, transformed the observatory into arguably the finest astrophysics institution in the world. With the founding of McDonald Observatory in 1939, Struve established an 82-inch reflector at a first-rate site in Texas. He swept out Frost's deadwood and hired an international cast of scientists who either were or were soon to become world leaders in astrophysics: Gerard Kuiper (Holland), William Morgan (US), Bengt Strömgren (Denmark), Jesse Greenstein (US) and, most notably, Subrahmanyan Chandrasekhar (India). When Struve hired him in 1936, "Chandra" had already developed the theory of white dwarf stars, for which he was to receive a Nobel Prize 50 years later, but had suffered from intellectual and racial prejudice. It is telling that Struve also had to overcome resistance to Chandra's dark skin, and once resorted to the following rationale with a dean: "His complexion is of course quite dark but his features are quite different from those of the American Negro."

Osterbrock's account is a blend of a detailed chronology and a history. He supplies myriad details of hirings and firings, negotiations between astronomers and administrators and the financial shaping of the observatories. The book nicely lays out the ways in which varying research–management styles and personalities of directors can mightily influence the course of science. But, although such information is indispensable for assembling the history of 20th-century astronomy, there is little guidance to a larger context: Why should the reader care about Yerkes Observatory and the machinations of its staff? Nor is this study set into the larger context of the voluminous historical research on scientific institutions. Nevertheless, the book is solidly researched, full of fascinating stories and, for historians and astronomers, an important reference about one of the key American observatories of this century.

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An Introduction to X-ray Crystallography

Michael M. Woolfson
Cambridge U. P., New York, 1997. 2nd edition. 402 pp. $99.95 hc ($37.95 pb)
ISBN 0-521-41271-4 hc (0-521-42359-7 pb)

We have had to wait almost 30 years for the second edition of Michael M. Woolfson's widely acclaimed text, *An Introduction to X-ray Crystallography*. In a sense, it is humbling that so little has changed in the basic principles of crystallography during that time; almost all of the clever ideas were current, or at least well into formation, in 1970, when the first edition was published. The present-day revolution in crystallography is, after all, in its numerous applications to biology and materials science.

Crystallography is the epitome of interdisciplinary science. Its foundations are squarely in the physics of diffraction. Today, its numerous users are largely interested in structural