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 chemistry and, more recently, biology. They are well served by a clear introductory text such as this one.

Woolfson is a theoretical physicist who recently retired from the University of York. He is one of the inventors of "direct methods," the nonlinear mathematical and computational wizardry that allows the complete solution of an atomic crystal structure at the touch of a carriage return. He is the author of the program MULTAN, which is probably responsible for half of the crystal structures ever solved. He happens also to be expert in the origin of the Solar System.

A direct method is any procedure capable of inverting crystallographic data without recourse to further information about the crystal. The most widely used methods originate from an equation, by David Sayre in 1952, that interrelates the various complex amplitudes of different orders of diffraction. The internal self-consistency of the data puts constraints on the phases of the reflections, which are not measured in the experiment but which are needed to know the structure. In 1956, Jerome Karle and Herb Hauptman proposed a "tangent formula" to estimate the phases from the set of amplitudes. That formula is now the basis of programs such as MULTAN. Direct methods revolutionized crystallography and earned Karle and Hauptman the 1985 Nobel Prize in Chemistry.

Woolfson uses a third of his book to lead the reader to the subject of diffraction. In this, he makes few blind assumptions and ingeniously uses the opportunity to teach some basic physics—mechanical models of resonance, for example—to readers whose background might lie closer to chemistry or biology. His preference for elegant geometric pictures, with illuminating diagrams, over the mathematical rigors of reciprocal space is designed to retain this audience. His geometric construction of three-dimensional diffraction via one and two dimensions is noteworthy.

The book, like crystallography itself, is practical. It has helpful rules of thumb that encourage the practitioner to try more than one method in tackling a problem. Recognizing the widespread literacy in computers, Woolfson has in the new edition replaced the section on optical methods of interpreting diffraction patterns with a number of worked computations. FORTRAN codes are provided for the exercises, worked into both the text and the problems at the end of each chapter. Though concise, some of these codes are computationally fairly sophisticated—a simple two-dimensional direct-methods code based on the tangent formula, for example.

Because it is intended as an introduction to the subject, the book stops short of covering a number of powerful analytic methods in common use today. Patterson methods are discussed at length, but not the automated search methods or the rotation function for locating symmetry elements. There is little discussion of noncrystallographic symmetry and its virtue in the solution of structures. Multiple-wavelength anomalous dispersion and maximum entropy are not mentioned. Refinement procedures do not cover simulated annealing or the computer-graphical approaches to model building.

Woolfson also steers clear of diffraction from imperfect crystals, disorder, interfaces and thin films, which are covered in other introductory texts—for example in B. E. Warren's *X-ray Diffraction* (Addison-Wesley, 1969).

The organization of Woolfson's book divides cleanly into two halves, following the classical division of the subject: the acquisition of structure-factor data followed by its interpretation. In summary, it remains an excellent introductory text, aimed at a chemistry and biology audience. Its strengths are its conceptual explanation of the physics of diffraction and its practical guidance in the solution of crystal structures.

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Scaling and Renormalization in Statistical Physics

John Cardy
Cambridge U. P., New York, 1996. 238 pp. $32.95 pb
ISBN 0-521-49959-3

John Cardy's *Scaling and Renormalization in Statistical Physics*, part of the Cambridge Lecture Notes in Physics series, is designed as a broad introduction to scaling and renormalization theory of phase transitions. Detailed theoretical discussions are avoided, and there is no attempt to look at the relation to experimental physics. No references to original sources are given, but there is an extensive bibliography for each chapter, referring to more detailed reviews of the topics covered. At the end of each chapter is a selection of problems.

The book opens with surveys of phase diagrams and mean field theory and then discusses renormalization group theory of simple critical points, taking the discussion up to but usually not beyond first-order perturbative results. The second half of the book discusses low-dimensional systems, surface critical behavior, random systems, polymers, critical dynamics and conformal invariance.

The first half covers material that has already been developed in most of the many treatments of the renormalization theory of critical phenomena that have been written in the past 25 years. I noticed at least one point where Cardy's text is seriously out of date: The table on page 100 shows a comparison of critical exponents calculated by the epsilon expansion, from the renormalization group equations and from high-temperature series expansions, and the author states that a significant discrepancy exists between the results given by the different methods. Ways to analyze confluent singularities were applied to this problem more than 15 years ago, and the discrepancies more or less disappeared.

Cardy has made significant contributions to almost all the topics covered in the second half of the book, and he has been one of the leaders in developing the use of conformal invariance in statistical mechanics, which is the subject of his last chapter. He writes as an expert, but I, who am much less expert in this area, found some of his economical explanations baffling. In places, I found his line of thought clearly stated and full of insight, but then lost the track and had to go back very carefully over the text. Cardy's choice of topics is good, but I am not convinced that he has provided sufficient detail for a reasonably good graduate student to follow his arguments.

In a few places, I thought that the author's desire to give a neat explanation led him astray. For example, in his discussion of the Blume–Capel model on page 62, he writes, "At finite but low temperatures, this first-order transition must persist for some distance into the phase diagram, since the thermodynamic quantities are not sin-