Pillow" with the great pleasure it deserves.

Mermin's collection is delightful for browsing, but it is certainly not for study "all the way through."

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New Developments in the Theory of Knots

Edited by Toshitake Kohno
World Scientific, River Edge, N. J., 1990. 906 pp. $86.00 hc
ISBN 981-02-0162-1

The Geometry and Physics of Knots

Michael Atiyah
Cambridge U. P., New York, 1990. 78 pp. $39.50 hc
ISBN 0-521-39521-6; $15.95 pb
ISBN 0-521-30554-2

The Geometry of Four-Manifolds

S. K. Donaldson and P. B. Kronheimer
Oxford U. P., New York, 1990. 440 pp. $75.00 hc
ISBN 0-19-853553

Over the last decade we have witnessed a renaissance of the interaction between physicists and mathematicians, particularly geometers, that has had a profound influence on the development of both mathematics and mathematical physics. Not since the introduction of relativity and the acceptance of Riemannian geometry has physics had such an impact on geometry nor, conversely, have geometric methods been so important for the development of new physical theories. In fact, it is remarkable that several of the Fields Medals awarded at the last two International Congresses of Mathematicians went to contributors to this rapprochement. The three books reviewed here cover important areas of these developments, but before going into the details of their contents, I will try to place these developments in the perspective of a physicist.

The four-dimensional character of physical space–time has long been a subject of investigation: Is four-dimensional space-time the "best of all possible worlds," in which electromagnetic phenomena take on their simplest and most symmetrical form? Or is it the *only* possible world in which quantum fields can exist nontrivially? On the mathematical side,

low-dimensional manifolds have presented geometers and topologists with puzzles, some of which remain unsolved, such as Poincaré's conjecture in three dimensions. And here again four-dimensional manifolds have become the focus of attention in the last few decades. Inspired by Yang–Mills field theory, mathematicians, in particular S. K. Donaldson, have obtained spectacular results. These results form the subject of his book, coauthored with P. B. Kronheimer, *The Geometry of Four-Manifolds*, reviewed here.

Knots in three-dimensional space have not only interested sailors and mountaineers but have also been intensely studied by topologists. In the 19th century Kelvin put forward the idea—based on arguments of stability, variety and the possibility that the vibrational spectrum of vortex tubes might explain spectral lines—that atoms were knotted vortex tubes in the "ether." James Clerk Maxwell took this model seriously, and Peter Guthrie Tait came up with the first classification of knots. Some interesting results in knot theory were obtained in the 1920s (for example, by James Alexander and Kurt Reidemeister), but a definitive classification was not obtained until 1984, by Vaughan Jones.

Edward Witten and other physicists discovered the relationships of knot theory to string theory and to conformal quantum field theory, and these are now at the center of active developments. Michael Atiyah's "Lezioni Lincei" (lectures delivered at the Accademia Nazionale dei Lincei in Italy) of 1990 gives an overview of these developments, and his book *The Geometry and Physics of Knots* is a collection of reprints of original articles in which the reader can find all the details on knot theory. Although in his book Atiyah tries to preserve the lively style one knows from his lectures, the text does not quite convey Atiyah's enthusiasm and vivacity, to which one gets so easily accustomed. (The reader might well consider purchasing the videotapes from the American Mathematical Society of Atiyah's Gibbs Lecture of 1991, which have the added attraction of showing a live performance.)

The collection of reprints edited by Toshitake Kohno is a hefty 906 pages with 10 pages of references. I will not review this collection in detail. The reprints range from the now classic *Bulletin* (of the American Mathematical Society) notes by Jones and the joint paper by the four groups led by Peter Freyd and David Yetter, Jim Hoste, W. B. R. Likorish and Kenneth

C. Millet, and Adrian Ocneanu that describes the basic results they obtained independently and submitted for publication in September and October of 1984; through the hefty *Annals of Mathematics* paper by Jones; to "Applications in Statistical Mechanics," published in the *Journal of the Physical Society of Japan* by Y. Akutsu, M. Wadati and T. Deguchi in 1987 and 1988.

Other authors represented in this collection are Louis Kauffman, V. G. Turaev, A. N. Kirillov and N. Y. Reshetikhin, Jun Murakami, Hans Wenzl, Joan Birman and a number of others. About a quarter of the book is devoted to the relationships of knots and braids to conformal field theory, with representative papers by Kohno and A. Tsuchiya and Y. Kanie, a set of notes by Jürg Fröhlich entitled "Braid Statistics and the Yang–Baxter Equation"; a paper by Karl-Heinz Rehren and Bert Schroer called "Einstein Causality and Art in Braids" and the pioneering paper "Quantum Field Theory and the Jones Polynomial" by Witten (which is so enthusiastically described in Atiyah's book). This is definitely a book to which every worker and student in the field should have access.

I devote the remainder of this review to the book by Donaldson and Kronheimer. It recently has become customary in the mathematical literature that the first chapter of an article or book is the hardest to read, because it summarizes the contents at a level accessible to experts only and does not usually explain terms or motivation. Donaldson and Kronheimer's book follows this fad, but the physicist–reader should not be discouraged. Physicists should start with the second chapter, which is quite accessible and probably familiar to many who have been active in gauge theory. Nevertheless, it is imperative to return from time to time to chapter 1, which is well illustrated and meant to help the reader follow the thread of the book.

Here is a brief outline of the book's contents. Chapter 1 starts with an outline of what was known prior to around 1980 about smooth four-manifolds, and it includes a summary of results. Chapter 2 discusses connections, curvature, the antiself-duality equations and their relationship with holomorphic bundles (the instanton equations and a proof of Karen Uhlenbeck's existence theorem of local Coulomb gauges). Chapter 3 presents a self-contained and original formulation of the Atiyah–Drinfel'd–Hitchin–Manin construction, which gives a complete and concrete description of all solutions to the antiself-duality equations over the four-sphere (instantons). Chapter 4 discusses the general theory of the moduli spaces of antiself-dual Yang–Mills connections (instanton potentials) and some of their basic properties, and presents a new and simpler proof of Uhlenbeck's theorem on removable singularities. Chapter 5 shows how rational homology and Poincaré duality of a smooth, simply connected four-manifold X is captured by the cohomology of the space of all connections in a principal SU(2) bundle over X (another example of how Yang–Mills theory produces significant mathematics).

Chapter 6 describes the antiself-dual moduli spaces over complex Kähler surfaces in terms of stable bundles. This chapter will be difficult, at least for physicists, and is quite technical, but it provides new, simplified proofs. Chapter 7 treats

various topics from analysis that are related to the description of solutions of differential equations depending on a parameter. In particular it provides a guide for gluing antiself-dual connections over connected sums; this section requires the deepest analysis of any in the book, and it utilizes ideas that come from Clifford Taubes. Chapter 8 puts to work the geometry and analysis of the preceding sections. In particular, Donaldson's results on the intersection form of smooth four-manifolds are presented. Chapter 9 applies the study of the antiself-dual moduli spaces to uniqueness questions for smooth four-manifolds, and Donaldson's polynomial invariants are defined and used to show that K3 surfaces do not decompose. Chapter 10 shows how, using the material from Chapter 6, one can compute the invariants of Chapter 9 for algebraic surfaces. In particular, the authors show that a simply connected complex projective surface has nonvanishing Donaldson polynomials.

On the whole, the three books reviewed here will be useful additions to physics libraries, although only hardy mathematical physicists can be expected to read all three from cover to cover.

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NEW BOOKS

Astronomy and Astrophysics

Astronomical Photometry: A Guide. C. Sterken, J. Manfroid. Kluwer, Boston, 1992. 272 pp. $89.00 *pb* ISBN 0-7923-1776-9

The Astronomer's Sourcebook: The Complete Guide to Astronomical Equipment, Publications, Planetariums, Organizations, Events and More. B. Gibson. Woodbine House, Rockville, Maryland, 1992. 304 pp. $19.95 *pb* ISBN 0-933149-43-3

Astrophysical Data: Planets and Stars. K. R. Lang. Springer-Verlag, New York, 1992. 937 pp. $59.99 *hc* ISBN 0-387-97109-2. *Reference*

Astrophysical Techniques. Second edition. C. R. Kitchin. Adam Hilger, Bristol, UK (US dist. AIP, New York), 1991 [1984]. 480 pp. $67.50 *hc* ISBN 0-7503-0137-6

Astrophysics on the Threshold of the 21st Century. N. S. Kardashev, ed. (translated from the Russian by D. F. Smith). Gordon and Breach, Philadelphia, 1992. 379 pp. $90.00 *hc* ISBN 2-88124-817-9. *Compilation*

Dust in the Galactic Environment. *The Graduate Series in Astronomy.* D. C. B. Whittet. IOP, Bristol, UK (US dist. AIP, New York), 1992. 295 pp. $95.00 *hc* ISBN 0-7503-0204-6

The Early Observable Universe From Diffuse Backgrounds. Proc. Mtg., Les Arcs, France, March 1991. B. Rocca-Volmerange, J. M. Deharveng, J. T. T. Vân, eds. Editions Frontiéres, Gif-sur-Yvette, France, 1991. 437 pp. $60.00 *hc* ISBN 2-86332-107-2

Gamma-Ray Bursts: Observations, Analyses and Theories. Proc. Wksp., Taos, N. M., July–August 1990. C. Ho, R. I. Epstein, E. E. Fenimore. Cambridge U. P., 1992. 499 pp. $69.95 *hc* ISBN 0-521-41449-0

High Energy Astrophysics. *Particles, Photons and their Detection 1.* Second edition. M. S. Longair. Cambridge U. P., New York, 1992. 418 pp. $69.95 *hc* ISBN 0-521-38374-9

High-Energy Radiation from Magnetized Neutron Stars. P. Mészáros. Chicago U. P., Chicago, 1992. 531 pp. $39.95 *pb* ISBN 0-226-52094-3