

of a UNESCO conference. Because of a bureaucratic error, he had a visa for two weeks but only enough funds for the two remaining days of the conference. With typical resourcefulness and a burning desire to see Paris, he rationed his limited resources so that he could buy a round-trip Metro ticket, a sausage and a bag of apples each day while joyfully sampling the sights and sins of Paris.

In a moving story, Shklovsky portrays his 1941 escape from the German attack on Moscow in a train crowded with other students from Moscow University. One of the undergraduates in his train car asked Shklovsky, the senior member of the group, for a physics book to read. Mischievously, Shklovsky gave the young student a German-language copy of Walter Heitler's *Quantum Theory of Radiation*, difficult reading under the best of circumstances. With obvious admiration, Shklovsky, who claimed he "couldn't get through the first paragraph," tells of his surprise when the book was later returned by "the kid," who had apparently read the whole volume with complete understanding. Shklovsky relates how 30 years later he presented the same miraculously preserved book, to that former student on the occasion of the latter's 50th birthday. The recipient was Andrei Sakharov. Curiously, in his own memoirs, Sakharov tells of reading Shklovsky's then unpublished story, but he denies that the event in the train ever occurred. Such is the imperfect memory of great men.

Five Billion Vodka Bottles to the Moon is required reading for anyone—scientist, politician or concerned human being—who wants to understand better the unexpected events now occurring in Russia.

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Fractional Statistics and Anyon Superconductivity

Frank Wilczek

World Scientific, Teaneck, N. J., 1990. 447 pp. \$68.00 hc ISBN 981-02-0048-X; \$28.00 pb ISBN 981-02-0049-8

The quantum mechanics of many-body systems revolves around the requirement that simply relabeling indistinguishable particles cannot alter an observable quantity. In three or more spatial dimensions this restriction permits only two classes of particles—bosons and fermions—depending on whether permuting a pair is accompanied by a phase factor of

plus or minus one. A unique feature in two spatial dimensions is that one can keep track of the number of times a particle has encircled another; the principles of quantum mechanics are then consistent with associating a phase with each encirclement. This phase factor is not constrained *a priori*, and it specifies a continuum of possible quantum statistics in two dimensions (in the same way that the ± 1 factor for exchange specifies the two possibilities in higher dimensions). (See *PHYSICS TODAY*, November 1989, page 17.) Excitations that possess these intermediate statistics, dubbed anyons, are found in the fractional quantum Hall effect. Anyons arise naturally in $(2+1)$ -dimensional quantum field theories, and they have recently aroused interest as possible charge carriers in doped copper oxides.

Frank Wilczek's *Fractional Statistics and Anyon Superconductivity* offers a lucid introduction to the elementary physics of anyons. In a relaxed, conversational style, Wilczek leads off the volume with a pair of monographs that discuss the conceptual and formal underpinnings of fractional statistics and address the physics of many-anyon systems. The last three-quarters of the book consists of over two dozen articles reprinted by Wilczek and others.

Since the phase factor associated with carrying one anyon around another specifies the allowed relative angular momentum of a pair, a many-anyon wavefunction must satisfy cumbersome boundary conditions that force it to be multivalued. A more economical way to introduce the required phase factors is by means of the Aharonov-Bohm effect—for example, by formulating anyons as charged fermions (or bosons) attached to magnetic flux lines of the appropriate strength. Wilczek deftly leads the reader through the subtleties of this procedure and shows how fractional statistics arise naturally in $(2+1)$ -dimensional quantum field theories with Hopf and Chern-Simons terms as their Lagrangians.

Readers seeking further insight into the conjectured relationship between anyons and high-temperature superconductivity may be somewhat disappointed. The "anyon superconductivity" of the title refers to the superfluidity of certain ideal anyon gases, which support long-lived longitudinal sound modes (and can therefore carry persistent currents) and have a gap to transverse excitations (permitting only irrotational superflow and implying the expulsion of external magnetic fields). As Wilczek

notes, the proposed connection between anyon gases and electrons in copper oxides remains quite tenuous, and the discussion of these issues is found primarily in the book's reprinted articles on chiral spin liquids.

Experiments to detect the breaking of time-reversal and reflection symmetries in high-temperature superconductors (which would necessarily arise if anyons were involved) are not encouraging for anyon models. (See *PHYSICS TODAY*, February 1991, page 17.) A complete discussion of the role of anyons in high-temperature superconductivity (if any) will have to wait for a future edition.

Aficionados of fractional statistics will find many of their favorite articles reprinted here—from Yakir Aharonov and David Bohm's classic 1959 paper on vector potentials in quantum mechanics to Xiao-Gang Wen, Wilczek and Anthony Zee's 1989 work on chiral spin liquids. Because it is the best-known physical phenomenon displaying anyonic excitations, the fractional quantum Hall effect is prominently featured, as are several papers concerning frustrated-spin systems and the superconductivity of anyon gases. These reprints complement an extensive selection of articles on the conceptual and technical foundations of fractional statistics.

This timely volume offers a clear introduction to the rudiments (and some of the esoterica) of fractional statistics. It should be accessible to anyone with a graduate-level background in quantum mechanics and elementary field theory. In addition to guiding the reader around the "circle of ideas" associated with fractional statistics and anyon superconductivity, the book also provides a thought-provoking refresher course in superfluidity and the quantum mechanics of indistinguishable particles.

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Space Commerce

John L. McLucas

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John McLucas defines space commerce as "those activities in which private companies put their money at risk to offer goods and services that depend on having satellites in orbit." In this book he includes chapters on communications satellites, remote sensing, navigation, habitations in space and materials processing. I found his accounts of these develop-