BOOKS: APPLIED PHYSICS

Precise Timing

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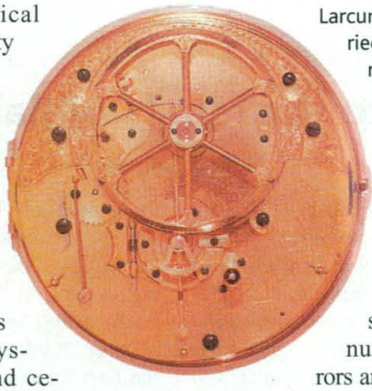
Time and timekeeping are pervasive elements in all of our lives. We reap the benefits of extremely precise timekeeping through technologies ranging from cell phones to the global positioning system. This positioning system relies on a worldwide array of satellite-borne atomic clocks that remain synchronized within fractions of microseconds, which allows positions anywhere on Earth to be determined within a meter. Atomic clocks are devices that use the oscillation rate of an internal feature of an atom—rates that are typically several gigahertz—as their "ticking" rate. The most famous of these clocks is based on the cesium-133 atom, whose transition frequency between two hyperfine states defines the second. Fouad G. Major has made significant contributions to the measurement of atomic frequencies. In *The Quantum Beat*, he offers nonspecialists an informative, technical description of atomic clocks.

The Quantum Beat
The Physical Principles of Atomic Clocks
by Fouad G. Major
Springer, New York, 1998. 489 pp. $49.95. ISBN 0-387-98301-5.

The book is written at the level of advanced undergraduates and introductory graduate students, but Major attempts to present the basic operating principals without covering all the details of the sometimes quite-involved calculations. He provides a reasonably good overview of the different types of atomic clocks, although the quality of his detailed descriptions varies widely. The book occupies a niche that is restricted by the presence of Vanier and Audoin's much more technically detailed and comprehensive *The Quantum Physics of Atomic Frequency Standards* (*1*), two volumes that total over 1500 pages.

Major begins with brief accounts of the workings of various celestial and mechanical clocks. He then provides a fair amount of background on oscillations and oscillators, using a minimum of mathematical formalism. In these sections, the author errs by not including a better description of the stability characterization of clocks and oscillators. In fact, his treatment of the Allan variance (a statistical measure of the repeatability of a clock's or oscillator's frequency when it is observed for a given length of time) is seriously flawed. A few pages spent describing this critically important stability metric would have greatly improved the book. Nonetheless, Major's discussions of quartz crystals, rubidium clocks, and cesium-beam clocks can serve as an excellent introduction to the basic operation of these devices.



Larcum Kendall's K-2 (1772), carried to Pitcairn Island after the mutiny on the *Bounty*, was a cheap imitation of the watch that won John Harrison the longitude prize.

The high level of detail lavished on ion-trapping theory reflects the author's background. Ion-trap frequency standards are treated extensively, but narrowly in scope. Particularly disappointing are the absence of any mention of the mercury-ion work at the Jet Propulsion Laboratory (*2*) and the minimal coverage of results from the stored ion group at the National Institute of Standards and Technology (as compared to the extensive treatment given the author's own work). These sections on trapped-ion standards read more like a technical review article on the author's research than a text intended for readers who have only a general background in physics and engineering.

For many of the topics covered, the number of references and citations is disappointingly small. In addition, there are numerous typographical errors and several figures are poorly constructed to the point of being misleading. I found, however, that all of these small errors could be corrected from context.

All in all, I can recommend *The Quantum Beat* to newcomers to atomic clocks, with the caution that additional reading would be critical before embarking on a project within the field. For those readers interested in actually building or working on atomic clocks, Major's book will not replace Vanier and Audoin's comprehensive treatment.

References and Notes

1. J. Vanier and C. Audoin, *The Quantum Physics of Atomic Frequency Standards* (Institute of Physics Publishing, Bristol, UK, 1989).
2. R. L. Tjoelker, J. D. Prestage, G. J. Dick, L. Maleki, *Proc. 1994 IEEE Frequency Control Symposium*, p. 739. See also page 755.

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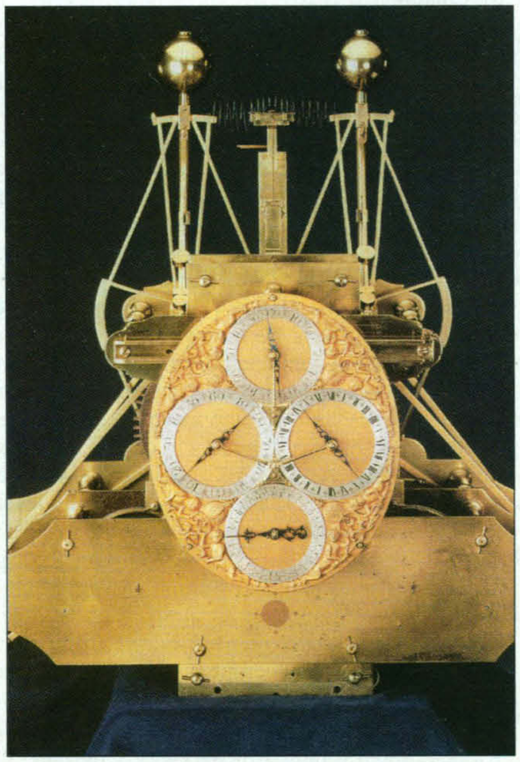
BROWSINGS



The Illustrated Longitude. *Dava Sobel and William J. H. Andrewes.* Walker, New York, 1998. 224 pp. $32.95. ISBN 0-8027-1344-0. Fourth Estate, London, 1998. 224 pp. £25. ISBN 0-85702-714-0.

Sobel's best-selling 1995 book championed the clockmaker John Harrison's successful, if insufficiently recognized and rewarded, solution to the problem of determining east-west locations at sea. This edition supplements her narrative with illustrations selected and explained by Andrewes, curator of Harvard's collection of historical scientific instruments. Harrison completed his first sea clock, the two-foot-tall H-1 (**left**) of 1735, after five years of work. Following Harrison's 1759 masterpiece—a dependable chronometer only five inches in diameter—British efforts were focused on more affordable designs (**above**).

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