Telling time in Tokugawa Japan

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Citation: Physics Today **72**, 6, 57 (2019); doi: 10.1063/PT.3.4229
View online: https://doi.org/10.1063/PT.3.4229
View Table of Contents: https://physicstoday.scitation.org/toc/pto/72/6
Published by the American Institute of Physics

the course of his quest. He describes his struggles with unreliable sources, competitors, and skeptics. His approach—assembling a "red team" of critics and a "blue team" of advocates that engaged in friendly competition until the scientific truth was revealed—is a formidable demonstration of how to avoid confirmation bias. Finally, and this I find a particularly important moral, Steinhardt uses his personal perspective to demonstrate that scientific discovery is often not a solitary effort. Instead, true progress comes from openness to the world and the acceptance of potential failure. The events described in the book are an extraordinary display of tenacity and serendipity, and the writing is captivating, entertaining, and full of fascinating scientific content. I strongly recommend *The Second Kind of Impossible* to experts and lay audiences alike.

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A pocket watch made for the Japanese market circa 1715.

Telling time in Tokugawa Japan

Yulia Frumer's *Making Time: Astronomical Time Measurement in Tokugawa Japan* will fascinate readers with its study of the evolution of different systems of time measurement in Japan. The book begins with the arrival of the first Western mechanical clocks during the Tokugawa (or Edo) period from 1603 to 1868, when the ruling shogunate restricted contact with foreigners and strengthened the country's traditional temporal system. The author then traces timekeeping technologies and systems through to the calendar reform of 1873, when the Japanese people wholeheartedly embraced Western methods of timekeeping.

Making Time
Astronomical Time Measurement in Tokugawa Japan
Yulia Frumer
U. Chicago Press, 2018. $45.00

In 17th-century Japan, Western clocks seemed nonsensical to consumers because they measured time in 24 equal hours and were dissociated from natural events like dawn and dusk. By contrast, the Japanese people divided their day into 12 unequal hours, following an ancient Chinese system introduced in Japan in the 7th century. Daylight and darkness were each split into six equal parts, no matter what the season. The daylight hours grew longer in the summer and shorter in the winter, with the reverse occurring for the nighttime hours. The hours of the day and night were equal in length only on the equinoxes. Each hour was named for 1 of 12 animal signs and was also given a number that could be used to announce the hour by strikes of a bell. Midday, for example, was Horse (9). A vestige of this system is still found in the modern Japanese expression that refers to morning as "before Horse" and afternoon as "after Horse."

Although sundials could find the time directly from the Sun overhead, water and fire clocks were commonly used to keep time. Incense clocks, a type of fire clock widely used in the Tokugawa period, had moveable hour markers placed in the sand alongside a trail of burning incense and required a standardized system for shifting the hour markers as the year progressed. The lengths of day and night hours were adjusted 24 times a year according to seasonal weather changes such as with the "beginning of spring," "rain water," "major heat," "cold dew," "frost descending," and "major snow."

Japanese users noticed that those seasonal weather markers were not in tune with Japan but with northern China, where the calendar had originated. Moreover, scholars saw the need to regulate the lunar calendar against the solar year so that the seasons would not drift. To that end, the central government established an astronomical bureau to manage and reform the calendar as needed.

Frumer notes that by the late 17th century, Japan had in place a standardized calendar and a single time zone for the entire country. She also shows how Japanese clockmakers reengineered Western mechanical clocks to keep variable hours and shape them to suit Japanese life. Weights on the ends of the foliot in early mechanical clocks were shifted as often as twice daily to speed up or slow down the passage of day or night hours. Later mechanical clocks had moveable digits, index arms with adjustable lengths, and faces marked with hour lines like sundials.

Frumer argues that Tokugawa astronomers became comfortable with Western clocks and the system of 24 equal hours during the 18th century, as they measured the motion of heavenly bodies along celestial arcs and timed star transits. In the context of longitude determination, the author says, astronomers came to see time as a mathematical "belt" wrapping around the globe and the universe behaving more like an equal-hour timepiece than a variable clock of the early Tokugawa period. By the Meiji period, when Japanese society opened up to international commerce, Western timekeeping practices had become associated with positive values such as convenience, social progress, science, and enlightenment. The equal-hour system had another advantage for the Meiji government: It shifted people away from divination practices and superstitions linked to the unequal hours and their animal associations. Thus, in 1873 the Japanese government mandated the use of the 24-hour clock.

Making Time is the most comprehensive treatment of Japanese timekeeping to date, but it is not a specialized book for horologists interested in detailed information about clock mechanisms and makers. Frumer's text is addressed to historians of science, technology, and Japanese culture. She deftly shows that technology is not just about practical needs; it is shaped by a society's values and activities. Frumer's book also prompts questions about technology transfer by showing how clocks from Europe that landed in Japan did not always have the same interpretation or use in their new environment. If the book has a shortcoming, it is that the narrow focus on timekeeping left me wishing for a broad history of Japanese methods of time finding and material culture. (I say this, admittedly, as the curator of a large collection of Japanese sundials.)

Time pluralism was also common in Europe during that time period, although Frumer doesn't make the point. Not only were the Gregorian and Julian calendars in simultaneous use, but solar time was read according to multiple systems of equal hours, which varied by geographical region and type of work, and the Catholic church also employed some timekeeping methods that used unequal hours. European pocket sundials enabled users to track the time in different systems, find the lengths of day and night in different seasons, and compensate for diverse latitudes. Those sundials shared similar functions with the clocks and astronomical activities discussed in Frumer's book, and their use was shaped by social needs in similar ways. That is not a criticism of the book; it is a note that Frumer's analysis has reach far beyond Japan.

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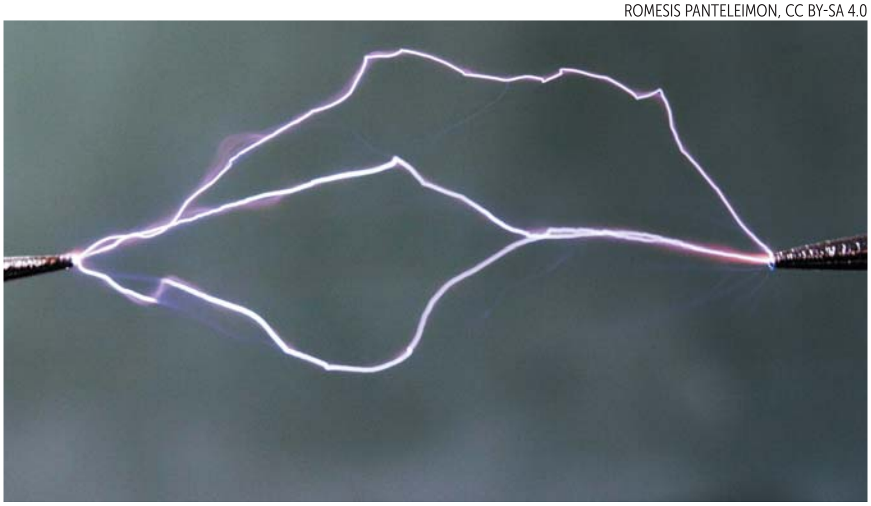
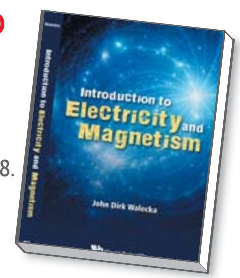


Electromagnetism textbook bridges the gap between basic and advanced

Introduction to Electricity and Magnetism
John Dirk Walecka
World Scientific, 2018. $48.00 (paper)



Several widely adopted physics textbooks in electricity and magnetism are available for undergraduates; they include *Introduction to Electrodynamics* by David Griffiths (4th edition, 2017) and *Electricity and Magnetism* by Edward Purcell and David Morin (3rd edition, 2013). For instructors and students hoping to supplement those books with a mathematically concise treatment, however, *Introduction to Electricity and Magnetism* by John Dirk Walecka would be a good companion text. A succinct treatment of the major topics in the field, it provides a bridge between basic and advanced textbooks.

Walecka is a well-known nuclear theorist and author of several undergraduate and graduate textbooks in nuclear physics, modern physics, and general relativity. *Introduction to Electricity and Magnetism* is divided into three sections and seamlessly transitions from electricity to magnetism and then to Maxwell's equations. Each section ends with a summary chapter of major concepts, a feature that readers will likely find useful. The assumption that the reader has already studied introductory classical mechanics and vector calculus enables Walecka to tackle more sophisticated mathematics than most introductions to the subject.

The first section covers the fundamentals of electricity, including Coulomb's law and electric fields, Gauss's law, elec-