

A sound introduction to the piano

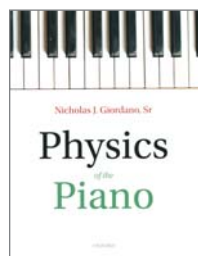
Physics of the Piano

Nicholas J. Giordano Sr
Oxford U. Press, New York, 2010.
\$59.95 (170 pp.).
ISBN 978-0-19-954602-2

Reviewed by Uwe J. Hansen

In just over 150 pages, *Physics of the Piano* manages to deliver remarkable depth for a text aimed at a broad audience—anyone who is interested in understanding how and why the piano was invented, how it evolved, and how different parts of the instrument contribute to the sound it produces. Like many of us musical-acoustics researchers, author Nicholas J. Giordano Sr—the Hubert James Distinguished Professor of Physics at Purdue University—came to the field rather late. But since his arrival, he has made significant contributions as evidenced by a number of his publications in the *Journal of the Acoustical Society of America* and invited presentations at that society's conferences.

Giordano offers in-depth discussions of fundamental physics principles relevant to music production, amplification, and propagation. In doing so, he follows in the tradition of Neville Fletcher and Thomas Rossing in *The Physics of Musical Instruments* (Springer, 1998) and Jürgen Meyer in *Acoustics and the Performance of Music: Manual for Acousticians, Audio Engineers, Musicians, Architects and Musical Instrument Makers* (Springer, 2009), which I translated. Giordano's accessible presentation also addresses topics not ordinarily considered by readers who are neither scientists nor musicians. Among those topics are nonlinearities



in the hammer-string interaction, longitudinal string vibrations, and “stretch” tuning due to the stiffness of piano strings (see John Bryner’s article about Richard Feynman’s letter to his piano tuner in *PHYSICS TODAY*, December 2009, page 46). Each is discussed within the broader context of musical scales, piano history, the vibrating string, the soundboard, psychoacoustics, and the magic of Steinway pianos.

Omitted are some important details such as practical effects of longitudinal-wave propagation in strings and effects of string scaling on the inharmonicities of higher partials. The author’s understandable love affair with the Steinway brand is evident throughout the book, and it serves well to illustrate details in piano development and technology. Unfortunately, Bösendorfer and Yamaha pianos are consequently relegated to mere parenthetical comments; other high-quality brands are totally ignored. Although additional low-register strings in the Bösendorfer might be rarely used, the increased size of the soundboard does affect the piano’s tone.

Also, both Bösendorfer and Yamaha manufacture electromechanical systems that are used extensively for training young virtuoso performers in developing performance techniques. The author mentions the Yamaha system but dismisses its value. And he ignores the Bösendorfer system that senses and records hammer velocity and key position, and uses those recorded parameters to drive solenoids behind the key pivot points to reproduce performance dynamics.

Anyone desiring additional scientific details should consult the extensive listing of references, which include a truly masterful list of historic and contemporary researchers. Three notable works are missing, however. The first, edited by Anders Askenfelt, is *Five Lectures on the Acoustics of the Piano* (Royal Swedish Academy of Music, 1990); the lectures were presented during a 1988 conference at the Royal Institute of Technology in Stockholm that also

included intensive discussions among piano researchers, performers, and manufacturers. A CD of performances at that conference is included with the lectures. The second missing publication is a December 1995 *Scientific American* article by E. Donnell Blackham that provides a wonderful lay-language introduction to the physics of the piano; the third is Meyer’s *Acoustics and the Performance of Music*, mentioned earlier, which includes a chapter on tonal characteristics of the piano and another on directional characteristics of piano sound.

In summary, I highly recommend *Physics of the Piano*. It is an accessible introduction to many standard and some esoteric principles involved in creating the piano sound. I intend to use it as a reference for my general-education class offered in the honors program at Indiana State University.

Neutrino

Frank Close
Oxford U. Press, New York, 2010.
\$18.95 (127 pp.).
ISBN 978-0-19-957459-9

In 2006 Oxford University physics professor and accomplished popularizer of science Frank Close was invited to write an obituary of nuclear chemist and physics Nobel laureate Raymond (Ray) Davis Jr. When that obituary won the UK Science Writer’s Prize for the “Best Science Writing in a Non-Scientific Context,” Close decided to expand it into a popular book.

Neutrino is the story of the elusive particle conjured by Wolfgang Pauli as a “desperate remedy” to save the law of conservation of energy. Pauli was hesitant about publishing his idea; he even turned down an invitation to present it at a conference in Tübingen, Germany. Instead, in a famous open letter to the conference attendees, addressed to the “Dear Radioactive Ladies and Gentle-



Uwe Hansen is professor emeritus in the department of chemistry and physics at Indiana State University, where his work on musical instruments includes research on near-field sound radiated by pianos. He is a fellow of the Acoustical Society of America and has served as chair of the ASA Technical Committee on Musical Acoustics.

men," Pauli described why he proposed the neutrino. (It's likely that neither he nor they were aware that their own bodies were radioactive—due to potassium-40 decaying in their bones—and emitting neutrinos, no less.)

Soon afterward Enrico Fermi developed a theory modeled after electromagnetism that described neutrino interactions. Several theorists worked out the interaction cross section of neutrinos with matter and found it to be exceedingly small, which led physicists to believe that there was no practical way of observing the neutrino. Despite that prevailing view, atomic physicist Bruno Pontecorvo, at one time Fermi's assistant, realized that however elusive neutrinos may be, they can be detected by observing the radioactive argon nuclei produced when a sufficiently intense neutrino source interacts with a large enough chlorine target.

Enter Davis, who, after joining the Brookhaven National Laboratory, was told to go to the library, do some reading, and choose a project. In searching the literature, Davis came across Pontecorvo's work and decided to give his idea a go. Thus began Davis's hunt for neutrinos produced by the Sun. Eventually, Davis teamed up with John Bahcall, who carefully calculated the neutrino-chlorine interaction cross section and the solar neutrino flux. Eventually, the hunt for neutrinos would involve many experiments that looked not only to the Sun, but also to reactors, accelerators, and the atmosphere.

Close tells the story well. In particular, he does an excellent job of describing the early 20th-century understanding of radioactivity that led to Pauli's "desperate remedy." Almost as good is the way Close charts our evolving comprehension of the origin of solar energy. The book is full of gems that would equally interest the casual reader and the professional physicist. Such tales include the story of the seminal paper by Fermi being rejected by *Nature* as "too speculative" and the comment by Bahcall, who heroically kept the solar-neutrino problem interesting for three decades, that the hardest thing he had ever done was wooing his future wife.

For a neutrino aficionado like me, this book is too short. It does not cover many fascinating aspects of neutrino physics and its history, and I think that some of the presentation will be difficult for the uninitiated reader to grasp; one example is the way Close distinguishes neutrinos from antineutrinos. Also, it is satisfying to see Pontecorvo given due credit, but another equally captivating figure, Ettore Majorana—

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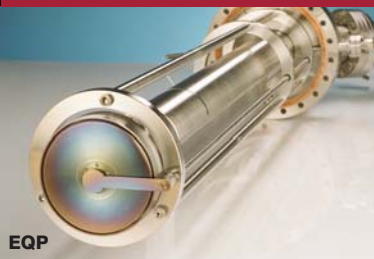
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also a Fermi protégé—is not mentioned at all. Consequently, alluring topics such as Majorana mass, neutrinoless double-beta decay, and the question of whether neutrinos are their own antiparticles are omitted. Perhaps Close wanted to restrict himself to experiments that have so far seen undisputed positive results.

Given Close's research focus in particle physics, it is no surprise that the particle aspect of neutrinos is covered in more depth than the role neutrinos—besides the solar variety—play in astrophysics. Astrophysical neutrinos are important because a neutrino's weak interactions allow it to travel very long distances in the cosmos, thus giving us a peek into the environment that created it. Perhaps in a subsequent edition astrophysical neutrinos will be covered in more detail.

Overall I much enjoyed reading *Neutrino*, and despite its minor shortcomings, I would recommend it as an excellent introduction to the subject. Three-quarters of a century after Pauli, neutrino physics is now a precise science. Many experiments, ongoing and planned, will doubtless reveal much more about these fascinating particles.

A. Baha Balantekin
University of Wisconsin
Madison

Atomic Force Microscopy

Peter Eaton and Paul West
Oxford U. Press, New York, 2010.
\$99.00 (248 pp.).
ISBN 978-0-19-957045-4

Since its invention in 1986, the atomic force microscope has found widespread application by researchers who desire images of surfaces at length scales from tens of microns down to atomic distances. Commercial AFMs (and much more, customized, laboratory-built ones) can probe unprepared or minimally prepared samples under ambient conditions, in liquids, and in ultrahigh vacuum at temperatures from 1 K up to hundreds of kelvin above room temperature. But despite the AFM's relative ease of use, achieving optimum results requires a good knowledge of its operational principles. As a frequent AFM user, I've been often asked, "Is there a book you would recommend for students who are new to AFM techniques?" For a long time there wasn't, but

now there's *Atomic Force Microscopy* by Peter Eaton and Paul West.

Of course, many other AFM-related books have been written, but they are either edited books in thematic series, books that focus on certain applications or specific operational modes, or books that are heavy on theory but light on practical recipes. Operation manuals are often a great place to start, but they vary in quality and focus on the manufacturer's hardware, thereby sacrificing the broader picture.

Atomic Force Microscopy provides the basic knowledge necessary for successful AFM operation while avoiding the trap of providing more detail than beginners can handle. It boasts seven chapters, each of them accessible and self-contained; readers can thus cherry-pick the topics of relevance for their specific problems. After a short introduction about the historical background and the contemporary context, the book covers practical issues such as understanding AFM design; working in operational modes; measuring, processing, and analyzing AFM images; and spotting and avoiding artifacts. For readers inclined to explore further uses, the book's last chapter discusses various applications that illustrate the multitude of measurement options available with AFMs.

The chapter on instrumental aspects exemplifies the kind of information presented in the book. In it, each component of an AFM is discussed in short, easy-to-read subsections that help the AFM novice to see the big picture despite a level of detail that might otherwise be overwhelming. For example, the subsection on scanners explains how they work, how they are typically integrated into the overall mechanical design, and how their deflection can be calibrated. It even discusses the nonlinear behavior of scanners, what that means for data acquisition, and how nonlinearities can be corrected.

One of the book's main strengths is that it is relatively short—183 pages of text; 138 if you disregard the applications chapter. Even at that length, it might be at the upper limit of what students are willing to handle. However, that brevity means some aspects could not be fully developed. In combination with the authors' decision to avoid mathematical formulas whenever possible, the brevity leads to what in my view is the book's most serious shortcoming: its discussion of oscillating-cantilever imaging modes. Those are among the

