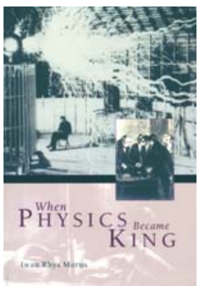
A Scientific Profession with Prominence

When Physics Became King

Iwan Rhys Morus
U. of Chicago Press, Chicago, 2005. $60.00, $25.00 paper (303 pp.). ISBN 0-226-54201-7, ISBN 0-226-54202-5 paper

Reviewed by Robert M. Brain

Iwan Rhys Morus's excellent history of physics in the 19th century, *When Physics Became King*, considers the field in an age when physics and physicists came to play a prominent role in the culture. Making physics the king of the sciences required more than simply producing powerful theories. It meant convincing people that the theories were true, that physics was the best way of finding out the truths of nature, and that such knowledge was important to society.



Morus, a leading historian of physics who teaches in the UK at the University of Wales, Aberystwyth, shows the magnitude of physicists' accomplishments. But the book's title also refers to the author's sense that physics may no longer reign as the king of the sciences. Today, science journalists look to molecular biology and the neurosciences to generate the excitement and novelty that physics used to provide. Still, physics remains a fundamental discipline, and physicists remain among the most trusted members of society. If physics occupies a throne, it reigns in a quieter fashion, more in the way of the kings of Spain or Sweden than of the British monarchs of the imperial age.

Against the background of the changing status of the field, Morus explores the ideas, institutions, and settings through which a new and international discipline was forged. He demonstrates that the rise of physics as an uncompromising discipline was accompanied by the strenuous efforts of physicists to define the field's social roles. Those varied roles might make much of 19th-century physics seem peculiar, even bizarre, to the 21st-century scientist. For much of the 19th-century, physics was a political hot potato, associated with materialism and secular modernity. Morus tells how physical theories arose in an arena that encompassed public shows, industrial entrepreneurship, and religious and cosmological considerations. Physicists like Michael Faraday, Hans Christian Oersted, and William Sturgeon became renowned public showmen, offering striking demonstrations of mechanical and, especially, electrical phenomena. Amid the arrays of batteries, galvanometers, induction coils, and magneto-electric machines, they provided models for the operations of natural systems before admiring audiences.

Many of those lessons had to do with utility and the burgeoning electrical industry. But the great physics exhibitions also drove home the point that the cosmos could quite literally be seen as being composed of machines analogous to the ones demonstrated by the electricians. Late Victorian models of the ether, with their gears and pulleys and wheels, bore the imprint of those worlds of industry and showmanship, and brought those worlds into accord with the religiosity of many great physicists of that age, such as James Clerk Maxwell and Lord Kelvin. Morus does not leave out those features of 19th-century physics that fail to conform to today's views of what physics is. Nor does he trivialize it with amusing anecdotes. Even in its colorful manifestations in exhibitions and shows, Victorian physics was a serious pursuit of sober men.

Physicists today might be particularly surprised to learn just how recently physics became an academic discipline. Throughout most of the 19th century, physicists were more easily found outside universities than within. They did not undergo similar training regimes but learned experimentation and problem solving in different settings and in a variety of traditions. Given the divergent spheres in which they worked, it is not surprising that 19th-century physicists were a far more varied bunch than their modern counterparts. During the second half of the century, however, the situation changed. Physics laboratories as we know them today began to appear in the 1860s, and physics departments only toward the end of the century.

Making physics an academic enterprise meant regularized regimes of training and opportunity. Morus examines the difficulties faced by the generation of physicists who established laboratory training. Physicists like Germany's Hermann von Helmholtz or the UK's Maxwell, Lord Rayleigh, and J. J. Thomson grappled with the best means to inculcate the skills of disparate practices of experimental physics to students of a new academic discipline. At the end of the 19th century, as many physicists began to believe that the general laws of the universe had been established and the end of physics was nigh, physicists set out to establish common metrological standards and push back the frontiers of precision measurement. Morus describes how the cult of precision gave purpose to the institutions of physics, securing thier privileged social position as the ultimate authority on nature. Those who had lived through the struggles to establish the prestige of their discipline and institutions worried that their gains could slip away. From a modern perspective, as Morus observes, their worries seem ironic: The social structures of physics proved much more durable than most 19th-century physical theories. A few good histories of physics during that remarkable age exist—but none as readable or comprehensive as Morus's superb book.

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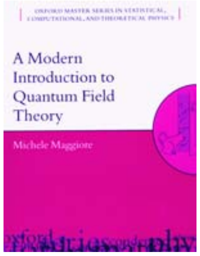
A Modern Introduction to Quantum Field Theory

Michele Maggiore
Oxford U. Press, New York, 2005. $114.50, $54.50 paper (291 pp.). ISBN 0-19-852073-5, ISBN 0-19-852074-3 paper

Quantum field theory, which marries the principles of quantum mechanics



and special relativity, is one of the great intellectual edifices of the latter half of the 20th century. It is the language of modern particle physics. It has also become an essential part of the theoretical tool kit of condensed matter theorists and has found fruitful applications in diverse other fields.

But few undergraduates ever get exposed to quantum field theory, despite its importance to modern theoretical physics. More or less universally, it is offered only as a graduate course. That is a pity. No one expects in an undergraduate-level course to be able to treat such an admittedly difficult subject in the same depth as one would in a graduate course. Yet that limitation has not stopped instructors from teaching undergraduate quantum mechanics alongside the more thorough graduate course. We would consider an undergraduate education in physics incomplete without at least one course in quantum mechanics.

Other difficult subjects, such as general relativity, are routinely offered as undergraduate courses in many institutions. Even string theory now has an undergraduate text, *A First Course in String Theory* (Cambridge U. Press, 2004), by Barton Zwiebach, based on his MIT course for seniors (see the review by Marcelo Gleiser, PHYSICS TODAY, September 2005, page 57). But no undergraduate text on quantum field theory had existed—until now. So I welcome Michele Maggiore's *A Modern Introduction to Quantum Field Theory*. In 291 pages he introduces the basics of perturbative quantum field theory, the renormalization group, gauge theories, and the standard model.

Graduate texts, such as Michael Peskin and Daniel Schroeder's *An Introduction to Quantum Field Theory* (Addison-Wesley, 1995) or Steven Weinberg's *The Quantum Theory of Fields* (Cambridge U. Press, 1995–2000), are too advanced for an undergraduate course. Many physicists think that Weinberg's two-volume opus on quantum field theory is too expansive, even for a standard full-year graduate course. Anthony Zee's *Quantum Field Theory in a Nutshell* (Princeton U. Press, 2003) is written at the right level for undergraduates but is not focused enough to serve as a good undergraduate textbook (see the review by Zvi Bern, PHYSICS TODAY, April 2004, page 88).

Obviously, many topics essential to the working field theorist are omitted in Maggiore's book. He develops the rudiments of scattering theory, the LSZ reduction formula, and tree-level cross sections and decay rates. Loop amplitudes are discussed qualitatively, but none of the technical machinery—for instance, the Feynman-parameter trick for combining denominators—necessary for actual computations is developed. The author gives a nice conceptual discussion of divergences in loop amplitudes, the need to renormalize, and how both lead to the modern picture of the renormalization group, but most of the nitty-gritty of renormalization theory is omitted. When he finally arrives at non-abelian gauge theories, he does not discuss the necessity of gauge fixing and the introduction of ghosts.

For the most part, the simplifications that Maggiore makes are innocuous; he manages to convey the main ideas without getting lost in technical details. But occasionally the simplifications get in the way of understanding. For instance, in discussing Goldstone's theorem, Maggiore breezily asserts that the generator of the spontaneously broken symmetry does not annihilate the vacuum and hence generates another state of the same energy. I think his assertion may leave the reader with a serious misapprehension that there is some big Hilbert space with a continuous degeneracy of states. In fact, although the charge density does exist as an operator, the global charge—the generator of the symmetry—does not. The vacua, which would have been related by the action of the generator, are in fact states in different Hilbert spaces.

All in all, Maggiore's approach is precisely the one that should be taken in an undergraduate course: Introduce the "big" ideas and leave the computational and thornier technical details for subsequent courses. Toward the end, the book contains a brief discussion of critical phenomena and concludes with an introduction to spontaneous symmetry breaking, the Higgs mechanism, and the standard model—all the bases one would hope to cover in a one-year course in quantum field theory.

Will Maggiore's text find a place in the undergraduate physics curriculum? I don't know. For the most part, we physicists are terribly conservative about our undergraduate curricula. The most ambitious undergraduates at the best institutions take refuge in graduate courses, which is not altogether a bad thing. But the act is not the same as our delivering challenging undergraduate courses worthy of students' attention.

Whatever its role in the undergraduate curriculum, Maggiore's text would benefit another audience: graduate students who are working to become high-energy experimentalists. They really do need to learn a smattering of quantum field theory, if only to be able to communicate effectively with their theorist colleagues. For most experimentalists, a course on the level of Peskin and Schroeder's book would be too heavy-duty. Consequently, most seem to shy away from tackling a course in quantum field theory. A course based on Maggiore's text would be much more suitable than the standard graduate course geared toward theorists. Throw a little more particle physics into its content, and the book would make for an excellent course for high-energy experimentalists. With any luck, such a course will become the norm.

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Death Rays, Jet Packs, Stunts and Supercars: The Fantastic Physics of Film's Most Celebrated Secret Agent

Barry Parker
Johns Hopkins U. Press, Baltimore, MD, 2005. $25.00 (231 pp.). ISBN 0-8018-8248-6

The Physics of Superheroes

James Kakalios
Gotham Books, New York, 2005. $26.00 (365 pp.). ISBN 1-592-40146-5

Following the enormous success of Lawrence Krauss's *The Physics of Star Trek* (Basic Books, 1995), we now have several attempts to take advantage of the surprisingly large market he discovered. Just fill in the blank: *"The Physics of ___,"* and one expects to have a winner. It sounds easy, but it isn't.

I frequently cite popular-culture images in my own introductory class, "Physics for Future Presidents," at the University of California at Berkeley. Thus I looked with eager anticipation to two new books—Barry Parker's *Death Rays, Jet Packs, Stunts and Supercars: The Fantastic Physics of Film's Most Celebrated Secret Agent* and James Kakalios's *The*