

A witty welcome to a weird world

Quantum Physics for Poets

Leon M. Lederman and Christopher T. Hill
Prometheus Books, Amherst, NY, 2011.
\$28.00 (338 pp.).
ISBN 978-1-61614-233-9

Reviewed by
Robert March

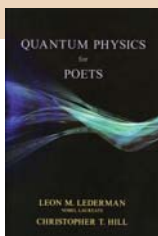
Anyone who is likely to open the covers of *Quantum Physics for Poets* has probably heard that the quantum theory is weird.

Leon Lederman and Christopher Hill do not hesitate to tackle that weirdness head on. It is introduced in the very first chapter, even before the exposition of the theory has begun.

The intended audience is clearly the well-educated lay reader who may have read or heard of quantum paradoxes in the popular press and is looking for a more systematic treatment. But I would also recommend this book to undergraduate physics majors who are struggling to master the machinery of quantum physics and would like to have a context in which to put their efforts.

The exposition unfolds in a conventional historical narrative, with a heavy reliance on double-slit interference as a central pedagogical device. The treatment is almost entirely non-mathematical. The writing is lucid and makes good use of the whimsical “borscht circuit” humor for which Lederman is justly famous among his colleagues. A window shopper at Victoria’s Secret illustrates the probabilistic behavior of photons and an exploding steakhouse in Kansas City illustrates constructive interference. In keeping with the theme of the book, Schrödinger’s cat and the Einstein-Podolsky-Rosen paradox are featured prominently. Some detailed treatments of more complex examples are relegated to an appendix, to avoid interrupting the continuity of the exposition.

Robert March is professor emeritus of physics and liberal studies at the University of Wisconsin–Madison and is the author of *Physics for Poets* (5th edition, McGraw-Hill, 2002).



Thumbnail biographies of the principal characters in quantum mechanics are well integrated into the text. Niels Bohr and Albert Einstein get their due canonization, but lesser figures are not neglected. The protean talents of Thomas Young are recounted in detail, and the birth of Schrödinger’s equation in a romantic alpine sojourn adds a bit of spice to the story. That equation is properly credited with gaining the acceptance of physicists uncomfortable with the aridity of Heisenberg’s matrix mechanics.

The core of the book is a deep discussion of Bell’s theorem, proposed and promulgated in 1964 by theorist John Bell at CERN. That focus is altogether appropriate, for it is Bell’s theorem, and the experimental confirmations that its crucial inequality is violated, that finally closed the door on any easy way out of quantum weirdness. Simply put, it shows that if any hidden variables exist they must be nonlocal. Entanglement—what Einstein called a “spooky action at a distance”—is observable.

I’m aware that Bell himself had hoped his theorem might provide a means to lay to rest the Copenhagen interpretation of the quantum theory. When the verdict of observation went the other way, he sadly concluded that we really don’t know what is going on. The section presenting the theorem makes demands to which some readers may not be able to rise. No higher mathematics is required, but some familiarity with statistics may be helpful. What is called for is the patience and concentration to follow a fairly complex logical argument that supports an odd and somewhat indirect statistical correlation. Of course, those who are not up to it can simply accept the conclusions and move on.

The narrative covers topics of current interest, including the standard model, supersymmetry, and string theory. It concludes with the hot topic of possible applications of quantum entanglement. Those include quantum cryptography, the woefully misnamed quantum “teleportation,” and quantum computing. There is one omission that I personally find disappointing: The word “decoherence” never appears. That concept holds that quantum ambi-

guity requires something approaching a perfectly isolated physical system. The collapse of the wavefunction requires no recourse to the consciousness of an observer. Any interaction with the outside world will do, and one can often measure the “decoherence time” over which it takes place.

Hill and Lederman have no patience with the New Agers who purport to find in quantum weirdness a deep spiritual message. The authors quote Steven Weinberg, the one physicist of my generation most deserving to be called a sage: “So irrelevant is the philosophy of quantum mechanics to its use that one begins to suspect that all the deep questions are really empty.”

Many of us who came to physics seeking deep understanding at first viewed that impasse with despair, which later gave way to acceptance, and finally, as Lederman would have it, to amusement.

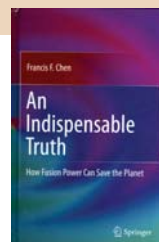
An Indispensable Truth

How Fusion Power Can Save the Planet

Francis F. Chen
Springer, New York, 2011.
\$49.95 (433 pp.).
ISBN 978-1-4419-7819-6

With *An Indispensable Truth: How Fusion Power Can Save the Planet*, Frank Chen has provided a sweeping perspective on fusion energy. He covers everything from climate change to plasma instabilities. On climate change and energy, the view is best from 30 000 feet: The book provides a good high-level overview of the issues at stake, but some of the details of his conclusions are not clear. On fusion plasma physics, Chen’s area of expertise, *An Indispensable Truth* provides an intuitive, up-close explanation of exciting recent advances and future challenges.

The book starts by reviewing the strong evidence that recent climate warming is anthropogenic, as well as the much weaker evidence that the planet may be nearing a tipping point,



such as might lead to the slowing of the Gulf Stream or a massive rise in sea level. However, Chen's analysis doesn't quite get to which actions we should be taking now. In my opinion, lacking the global will to pay today for strong reductions in carbon emissions, we must nevertheless strive to increase energy efficiency, deploy the most cost-effective low-carbon technologies, and perform the R&D for attractive future low-carbon options such as fusion. As the *R/P* (reserves divided by production) figures in the book show, fossil fuels are running out, so we will need new energy sources soon in any case.

Chen provides fascinating reviews of carbon-sequestration and renewable-energy technologies, but he is somewhat pessimistic on their application. He seems to conclude that the development of sequestration technology will take too long, and he maintains that renewables, due to their intermittency, cannot provide what he calls the world's "backbone power." But certainly we must do the R&D to understand if and where we can bury carbon safely, and energy and climate models generally project that something in the range of 30% of the world's electricity will come from

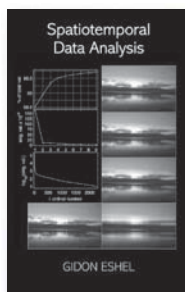
renewables by 2100, "backbone" or not.

In a short section on nuclear fission, Chen is more bullish; but, in my opinion, he underestimates the safety and proliferation risks. The meltdowns at the Fukushima Dai-ichi nuclear power plant following the Great East Japan Earthquake evidently came too late to be included, but now over 1% of the world's commercial fission reactors have been destroyed by accidents. To put proliferation risks in perspective, consider that nuclear fission may be called upon to provide about 30% of the world's electricity in 2100, given the limitations Chen notes on carbon sequestration—for example, the "Not Under My Back Yard" syndrome—and the intermittency of renewables (and assuming we have not developed fusion). In that scenario, fast-neutron-spectrum fission reactors could be required to reduce geological waste storage, to extend uranium resources, or both. A one-year supply of fuel stored at those reactors would hold, in sum, enough plutonium for about 1 million Nagasaki bombs.

When Chen gets to fusion—the energy solution that is the book's "indispensable truth"—he displays his signature ability to explain plasmas intuitively, without equations. He

shows how magnetic fields can contain plasmas, so long as their lines circumnavigate a toroidal confinement zone. He then shows why helical twist is needed in the field lines. He goes on to explain plasma instabilities, large and small, and even gives an explanation for why shear is needed in the helical twist to restrain the instabilities. He lays out the truly astounding advances that have been made both in the fusion performance of tokamaks, the best-developed magnetic configuration, and in the general scientific understanding of fusion plasmas. He includes intuitive explanations of such expert topics as H-mode, reversed magnetic shear, and internal transport barriers.

Chen is accurate in assessing that the greatest outstanding scientific issue for the tokamak is so-called disruption, where the confined plasma is suddenly lost to the chamber wall, possibly causing localized damage that would require a shutdown to repair. He correctly identifies the closely related stellarator configuration as the solution if disruptions prove too touchy to control in the tokamak. The book also outlines the outstanding materials-engineering challenge. ITER, a major international fusion project under construction in



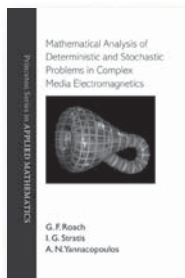
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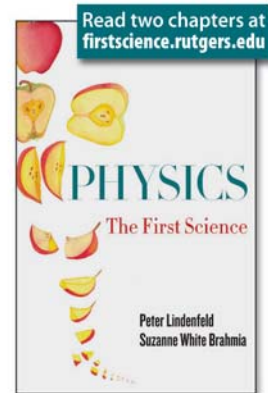
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France by China, Europe, India, Japan, Russia, South Korea, and the US, will demonstrate that fusion reactions can be energetically self-sustaining. The big remaining challenge will be to show how to manage the success that will come in the form of high power densities of both plasma and neutrons impinging on the first material surfaces.

Chen gives little credence to inertial confinement fusion, which is based on repetitive fusion microexplosions triggered by intense beams of energy, such as can be provided by lasers. Contrary to Chen's analysis, if the National Ignition Facility based at Lawrence Livermore National Laboratory produces high fusion gain from a laser striking a target that contains a deuterium-tritium capsule, I imagine that the fusion research community will want to further examine how this might be developed into a fusion-energy system. (A committee at the National Academies is reviewing that issue now.) There are short sections on cold fusion and bubble fusion, two ephemera that have proven not to be reproducible. Also discussed are future options for fusion fuels that do not produce neutrons.

The book concludes that leadership in fusion research has slipped away from the US to Europe and Asia. But the US could retake a leading position by addressing some of the outstanding materials engineering challenges or by developing advanced stellarators. Chen contrasts the present cost of magnetic fusion research—roughly \$400 million per year—with the Iraq war at \$100 billion per year and with NASA's budget. (Somehow NASA's annual budget is pegged at \$1.9 billion rather than \$19 billion. A number of such errors in the book suggest a too-rapid final edit.) It is clear that fusion and other promising energy R&D projects—particularly when their costs are compared with the correct NASA budget—merit higher priority.

An Indispensable Truth provides an exciting whirlwind tour of energy issues and technologies, with particular insight into fusion. Chen is correct to emphasize the tremendous progress that has been made in fusion research. ITER will produce hundreds of millions of watts of thermal energy from fusion, for periods of up to an hour. However, it remains for the world, and in particular for the US, to decide if we will develop fusion into a practical energy source. We will need it.

Robert Goldston
Princeton University
Princeton, New Jersey

Quantum Computing A Gentle Introduction

Eleanor Rieffel and Wolfgang Polak
MIT Press, Cambridge, MA, 2011.
\$45.00 (372 pp.).
ISBN 978-0-262-01506-6

How do you describe a masterpiece in a page or less? This is the pleasant problem I am facing in writing a review of *Quantum Computing: A Gentle Introduction* by Eleanor Rieffel and



Wolfgang Polak. I shall start by spending a few words on the topic.

The birth narrative of quantum computing is well known: Richard Feynman and others had some prophetic intuitions, David Deutsch and others tried the first formal approaches, and in 1994 Peter Shor demonstrated its potential by providing an efficient algorithm for integer factorization. At that point, the narrative usually goes badly astray. For instance, an algorithm proposed by Lov Grover in 1997 is typically brought to bear to solve an everyday problem that it cannot solve. I have even witnessed

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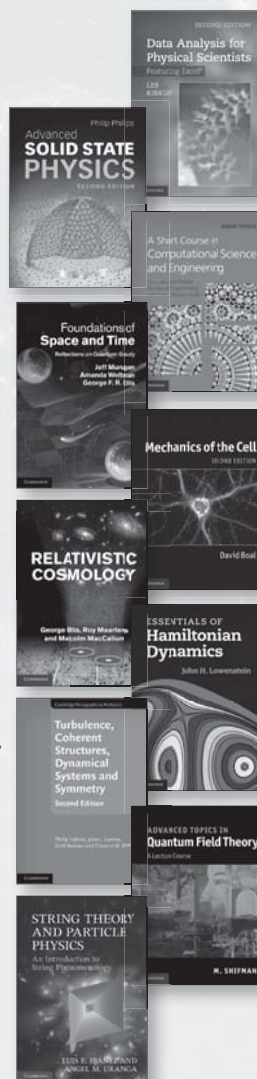
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