The Theory of Almost Everything: The Standard Model, the Unsung Triumph of Modern Physics FREE

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books

A modern model that deserves more respect

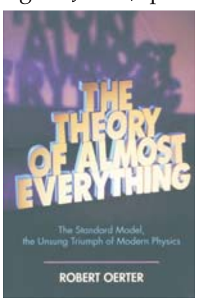
The Theory of Almost Everything

The Standard Model, the Unsung Triumph of Modern Physics

Robert Oerter

Pi Press, New York, 2006. $24.95 (327 pp.). ISBN 0-13-236678-9

Reviewed by Barry Holstein



The standard model, like the Roman god Janus, presents two faces to the world. To physicists, it is like Jacqueline Kennedy, chic and beautiful. But to the general public, it is like Rodney Dangerfield: It gets little respect. Robert Oerter, a physics professor at George Mason University in Virginia, has set out to change that popular misconception. In *The Theory of Almost Everything: The Standard Model, the Unsung Triumph of Modern Physics*, he attempts to give the standard model the respect it deserves. Does he succeed? Keep reading.

The task Oerter has undertaken is difficult because the standard model is not as sexy as the physics of black holes, string theory, extra dimensions, dark energy, dark matter, inflation, and so forth; and most casual readers have only a limited familiarity with many of the ideas that constitute the model. Physicists represent the standard model very simply by the gauge theories $SU(3) \times SU(2) \times U(1)$. The group $SU(3)$ signifies the gauge theory of eight color gluons coupled to quarks and to each other. The group $SU(2) \times U(1)$ is the electroweak theory, which unifies the weak and electromagnetic interactions and includes three massive gauge bosons in addition to the massless photon. One test then is to explain what those symbols mean to an audience that has not heard of most of the concepts. Thus Oerter describes what quarks, gluons, and gauge bosons are. That, however, is the easy part. The real challenge is that the standard model is a relativistic quantum field theory, which means that truly understanding it requires knowledge of relativity, quantum mechanics, fields in general, and quantum fields in particular. But there's more: To comprehend how relativity modifies Newtonian physics, one needs to understand Isaac Newton's *Principia*, which is also necessary to see how the new ideas are engendered by quantum mechanics. Understanding quantum fields requires knowing what a classical field is, and the best example is the electromagnetic field, so Oerter presents the contributions of James Clerk Maxwell.

The author undertakes all of these endeavors with élan. His style is entertaining and involves numerous simple and sometimes whimsical examples. For instance, in presenting time dilation, Oerter imagines a taxi trip to the airport in a world where the speed of light is only 30 mph. Assuming that the airport is 15 miles away and the cab travels 29 mph, the traveler must leave well over a half hour early but will arrive at the airport having aged only 10 minutes. To help readers grasp the idea of how a particle at a distance from a source can "sense" a classical field, the author introduces a homeowner whose neighbors are having a barbecue; the homeowner knows by the aroma that something is happening even if he or she is not invited. To explain the principle of least action, the author imagines a lifeguard who must save a floundering swimmer in the ocean. The path of least time does not involve a simple straight-line path but rather comprises two different straight-line paths—one on land, one in the water. I could continue, but you get the idea. The entire book is filled with similar examples, which are necessary to entice readers who have little knowledge of the standard model, or even of physics in general.

Of course, some of the arguments work better than others. Although Oerter uses an entire chapter to explain Feynman diagrams, I doubt if most readers will comprehend the meaning of the simple pictorial representations of complex underlying mathematical calculations, especially those diagrams with multiple loops. Also, it is hard to imagine that the concepts of colored gluons, Bell's theorem, and the Copenhagen interpretation of the wavefunction—all of which are discussed in the book—can really be understood by the casual reader.

Despite those minor reservations, I had fun with this book because it presents so many new and clever ways to explain basic physics to nonphysicists. What is not so clear to me is whether such readers can ever really hope to understand the many concepts involved in the standard model. In fact, I was struck by the huge number of crucial ideas in the book, such as quantum theory, relativity, quarks, and gluons, that practicing physicists must assimilate. Many of those concepts are nonintuitive. In my case, much of the comfort level was reached only after considerable repetition and detailed study. The casual reader has only one shot with Oerter's book. Nevertheless, the book gave me a lot of new ideas about how to answer friends who ask me what I do. Come to think of it, perhaps a professional physicist is not the best reviewer for Oerter's book. Maybe it should be reviewed by someone who has little or no knowledge of the field. Now that could be interesting.

I should also point out that in the final two chapters, the author does go beyond the standard model to consider the sort of ideas many popular books embrace—for example, dark matter, dark energy, inflation, grand unification, extra dimensions, the matter–antimatter asymmetry of the universe, supersymmetry, and string theory. None of those concepts are covered in depth in the two chapters; rather, they serve as a hook for the reader who is nibbling around the edge of standard model physics.

Reading *The Theory of Almost Everything* was overall a very satisfying experience, and I will enthusiastically recommend it to friends who are

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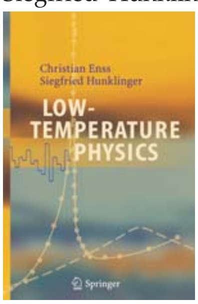
interested in understanding the essence of contemporary particle physics. Oerter is to be commended for successfully pulling off a challenging project, one that we physicists hope can possibly change this Rodney Dangerfield of theories into, if not a beautiful Jackie Kennedy, at least a model that gets more respect.

Low-Temperature Physics

Christian Enss and Siegfried Hunklinger
Springer, New York, 2005. $79.95 (573 pp.). ISBN 3-540-23164-1

Low-Temperature Physics is unique in the breadth of topics covered in one text and the extent to which it emphasizes the interconnectedness of various subjects, which is frequently lost in this age of specialization. Christian Enss and Siegfried Hunklinger have written an



extremely readable book that effectively treats most of the classical topics in a succinct yet reasonably complete manner; it also includes a survey chapter on experimental techniques. The book will be useful to students who are entering parts of the broader field of experimental condensed matter physics in which low temperature is a critical tool. The text provides background on foundational aspects of physics and explains the principles of cooling and thermometry in a manner that should make the operation of modern turnkey apparatus less mysterious.

With minor exceptions regarding discussions of the physics of liquid helium-3, the book can be easily read by students who know elementary quantum mechanics and statistical physics. Exercises at the end of each chapter make studying the subject material much less passive; they either illustrate important points or ask for numerical work that gives students a better quantitative understanding of the subject.

The book is divided into three parts, "Quantum Fluids," "Solids at Low Temperatures," and "Principles of Refrigeration and Thermometry." The first part covers the general properties of He; contains a masterfully written section on ^{4}He, which includes a clear description of the classical experiments and modern ones on macroscopic quantum behavior; and treats normal and superfluid ^{3}He and the properties of ^{3}He–^{4}He mixtures. The emphasis is always on the experiments and in most cases simple explanations of the phenomena. As with other parts of the book, citations to the original literature will help readers interested in details that cannot be included in a text of finite size.

The second part, on solids at low temperatures, starts with discussions of phonons and electrons, which greatly augment material covered in elementary books on solid-state physics. The authors then proceed to consider certain types of spin systems such as paramagnets, spin glasses, and systems exhibiting nuclear magnetic ordering. They even provide a section on negative spin temperatures. Some of the topics are important parts of what might be called classical low-temperature physics that are not generally included in conventional texts on solid-state or statistical physics.

Tunneling systems, the area of the authors' research, is usually not treated in as much detail in other contemporary texts. The topic involves a number of phenomena that are not yet fully explained, especially in the case of disordered systems. The discussion could have included additional material on electrical transport phenomena because they are an important part of contemporary research.

The treatment of superconductivity provides an excellent introduction to the phenomenology and includes accessible coverage of the Bardeen-Cooper-Schrieffer theory and macroscopic quantum effects. The chapter is not a substitute for any of the textbooks specific to superconductivity, such as Michael Tinkham's *Introduction to Superconductivity*, (McGraw-Hill, 1975), but it is adequate for someone working in another area or using such superconducting devices as SQUIDs, superconducting quantum interference devices. The section also contains brief discussions of some contemporary superconducting materials such as organic superconductors, the interplay of magnetism and superconductivity, heavy fermions, and high-T_c materials.

The final part of the book, on refrigeration and thermometry, was a delight to read. It clearly explains the principles of various commonly used techniques without going into too much technical detail. Chapters offer references to satisfy readers interested in more information.

In some ways, reading *Low-Temperature Physics* was a trip down memory lane because the book treats well the classical topics of the field of low-temperature physics, and it does an excellent job in about 550 pages. To a large extent, the subjects discussed are mature; many other topics could have been included or treated more extensively to give the book a more contemporary flavor. For example, the authors could have mentioned the physics of systems of reduced dimensions, such as those that manifest the integer and fractional quantum Hall effects. Also, the treatment of high-temperature superconductors and strongly correlated electron systems only scratches the surface of subjects that are the focus of intense work in the contemporary research environment. Despite such shortcomings, much is to be learned from Enss and Hunklinger's book. And students who read *Low-Temperature Physics* will benefit from it.

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The Equation That Couldn't Be Solved

How Mathematical Genius Discovered the Language of Symmetry

Mario Livio
Simon & Schuster, New York, 2005. $26.95 (353 pp.). ISBN 0-7432-5820-7

Hiding in the Mirror

The Mysterious Allure of Extra Dimensions, from Plato to String Theory and Beyond

Lawrence M. Krauss
Viking, New York, 2005. $24.95 (276 pp.). ISBN 0-670-03395-2

In hindsight one *could* judge these books by their covers. With its parchment-like background, multiple typefaces, butterfly photograph, and sprawling layout, Mario Livio's *The Equation That Couldn't Be Solved: How Mathematical Genius Discovered the Language of Symmetry* promises a richly detailed story linking life, history, and mathematics. Lawrence Krauss's *Hiding in the Mirror: The Mysterious Allure of Extra Dimensions, from Plato to String Theory and Beyond*, with its geometric graphics, single visual focal point, and subtle literary allusion, hints at the more streamlined story and argument within.