

Gauge Theories of the Strong, Weak, and Electromagnetic Interactions

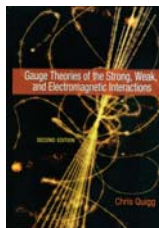
Chris Quigg

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Some 40 years ago particle theorists devised a theory that encompasses all the conventional matter of the universe and, gravity excepted, all the fundamental forces through which the matter interacts. That standard model of particle physics combines quantum chromodynamics—the modern theory of nuclear forces—with the electroweak theory developed by Sheldon Glashow, Steven Weinberg, and Abdus Salam; the Higgs boson predicted by that theory was discovered last summer at CERN's Large Hadron Collider (LHC). The ideas underlying the standard model are quantum field theory and spontaneous symmetry breaking, and the success of the model provides a striking confirmation of those ideas.



The physics that lies beyond the standard model remains a mystery. So far, the LHC has not revealed any information to help us determine it. However, a sneak peek into a part of the unknown world beyond the standard model has come from a succession of brilliant experimental results in neutrino physics during the past two decades. In addition, astrophysicists have made significant cosmological observations related to dark matter, dark energy, the inflationary expansion of the universe, and more. A vast new landscape of theoretical ideas and speculations that go far beyond the standard model has emerged in response to those discoveries.

At present the LHC is shut down, as teams are working to ramp up the machine's energy to its initially projected level before the search continues (hopefully in early 2015) for physics beyond the standard model. Meanwhile, neutrino physicists are gearing up for a new round of experiments to further probe neutrino properties. Answers to some fundamental questions in both cosmology and particle physics are likely to emerge from those experiments, and physicists are waiting with bated breath to see what new physics does or doesn't appear. Therefore, now

is an ideal time to summarize the remarkable developments in particle physics to date and the concepts on which they rest, so that the next generation of explorers will have not only a solid foundation to stand on but also a dependable roadmap to guide them.

The second edition of Chris Quigg's *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions* provides just such a foundation. Building on the 1983 first edition of the work, which was widely used as a textbook in advanced graduate courses, the new iteration achieves a new level of excellence and completeness that will make it a valued resource for graduate students and researchers. Quigg, who has made important theoretical contributions to the field, makes a different kind of useful and lasting contribution by writing this book.

Quigg starts with a summary of such basic concepts as constituents of matter, symmetries and conservation laws, and the idea of gauge invariance. That material essentially lays out the advances in the field that took place in the 1960s, when physicists introduced the idea of quarks and began to appreciate that the hidden symmetries in the weak force were local symmetries. He then describes developments such as the parton model of hadrons, non-abelian gauge theories, and spontaneous symmetry breaking—insights that led to the completion of the standard model in the following decade. Next Quigg discusses how gauge theories cured the pathological high-energy behavior of electroweak models and provides a detailed presentation of the various predictions of the standard model and how they were experimentally verified.

The book goes on to discuss neutrino oscillations and their implications for neutrino masses and other phenomena, and it covers all the essentials. Several books do a good job of presenting neutrino masses and their implications for physics, astrophysics, and cosmology, but Quigg's summary emphasizes neutrino masses as a pointer to physics beyond the standard model. The final chapter ventures beyond the standard model into the realm of grand unified theories. It discusses how such theories could provide a future pathway for the field and how discovery of baryon-number violation could provide a test of grand unification.

The chapters are thoughtfully arranged. For example, Quigg follows his presentation of the weak interaction of leptons with a discussion of the weak interactions of quarks; only then does

he consider the quarks' strong interactions. That last, complex topic rightfully takes the largest number of pages. The presentation is quite lucid and includes just enough technical details. Each of the main chapters is followed by a robust bibliography for readers who want more in-depth material.

On the whole, Quigg's book stands out for being clear and thorough while avoiding the heavy use of technical details that could obscure the basic physics. All the essential core topics of modern particle theory are covered. Several other books deal with aspects beyond the standard-model physics, such as supersymmetry, a topic not covered by Quigg, but none of those books are as up-to-date. *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions* will, for many years, remain as a standard textbook in particle theory. I highly recommend it for a two-semester advanced graduate course in particle physics and as a valuable addition to the collection of every particle physicist.

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Superconducting State Mechanisms and Properties

Vladimir Z. Kresin, Hans Morawitz, and Stuart A. Wolf

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The discovery of superconductivity—a combination of ideal conductance and ideal diamagnetism—has significantly changed condensed-matter physics and materials science. Superconductivity has fostered the development of new concepts in physics and new applications. And it has done so even though physicists have yet to devise a reliable microscopic explanation of the superconductivity in the high- T_c materials whose discovery precipitated a paradigm shift in the field. They haven't even reached consensus regarding the dominating mechanisms that govern superconductivity in the recently discovered new classes of high- T_c superconductors. As a result, experimental research into new superconductors that possess high- T_c and that can carry large current is an important driving force in materials science.

The field is now at a stage where a comprehensive survey is of extreme importance. That task is fulfilled by *Super-*