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Quantum Field Theory for the Gifted Amateur

By Tom Lancaster and Stephen J Blundell

Oxford University Press

Hardback: £65 \$110

Paperback: £29.99 \$49.95

Also available as an e-book, and at the CERN bookshop

Gauge Theories of the Strong, Weak, and Electromagnetic Interactions (2nd edition)

By Chris Quigg

Princeton University Press

Hardback: £52.00 \$75.00

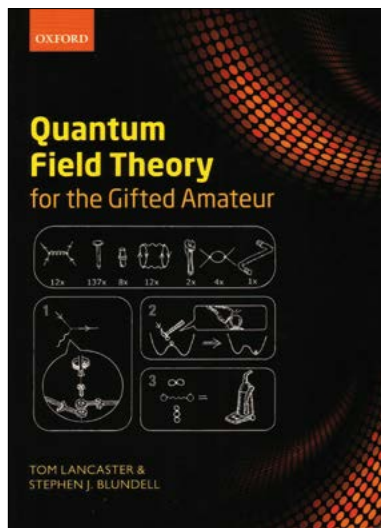
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Many readers of *CERN Courier* will already have several introductions to quantum field theory (QFT) on their shelves. Indeed, it might seem that another book on this topic has missed its century – but that is not quite true. Tom Lancaster and Stephen Blundell offer a response to a frequently posed question: What should I read and study to learn QFT? Before this text it was impossible to name a contemporary book suitable for self-study, where there is regular interaction with an adviser but not classroom-style. Now, in this book I find a treasury of contemporary material presented concisely and lucidly in a format that I can recommend for independent study.

Quantum Field Theory for the Gifted Amateur is in my opinion a good investment, although of course one cannot squeeze all of QFT into 500 pages. Specifically, this is not a book about strong interactions; QCD is not in the book, not a word. Reading page 308 at the end of subsection 34.4 one might expect that some aspects of quarks and asymptotic freedom would appear late in chapter 46, but they do not. I found the word “quark” once – on page 308 – but as far as I can tell, “gluon” did not make its way at all into the part on “Some applications from the world of particle physics.”

If you are a curious amateur and hear about, for example, “Majorana” (p444ff) or perhaps “vacuum instability” (p457ff, done nicely) or “chiral symmetry” (p322ff), you can start self-study of these topics by reading these pages. However, it’s a little odd that although important current content is set up, it is not always followed with a full explanation. In these examples, oscillation into a different flavour is given just one phrase, on p449.

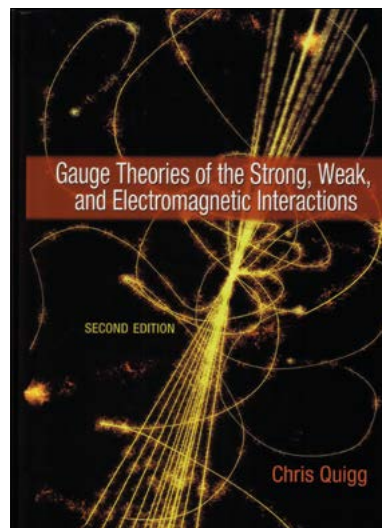
Some interesting topics – such as “coherent states” – are described in depth, but others central to QFT merit more words.



For example, figure 41.6 is presented in the margin to explain how QED vacuum polarization works, illustrating equations 41.18–20. The figure gives the impression that the QED vacuum-polarization effect decreases the Coulomb–Maxwell potential strength, while the equations and subsequent discussion correctly show that the observed vacuum-polarization effect in atoms adds attraction to electron binding. The reader should be given an explanation of the subtle point that reconciles the intuitive impression from the figure with the equations.

Despite these issues, I believe that this volume offers an attractive, new “rock and roll” approach, filling a large void in the spectrum of QFT books, so my strong positive recommendation stands. The question that the reader of these lines will now have in mind is how to mitigate the absence of some material.

The answer lies in the second edition of Chris Quigg’s *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions*. By a remarkable coincidence, this essentially revised volume fills in much of what the “gifted amateur” wants to know about how QFT is applied in traditional particle physics. It is hard to find words to describe Quigg’s clean, high-quality work; as an author he is a virtuoso performer. He takes the reader through the Standard Model of particle physics to the first steps beyond it, showing the most important insights, describing open questions and proposing original literature and further reading. He has designed or collected many insightful



figures that illustrate beautifully the intriguing properties of the Standard Model.

However, it’s hard for me personally to end the review on this high note since the research in the field of gauge theories of strong interactions does not end with the perturbative processes. Over the past 30 years, a vast new area has opened up with many fundamental insights. These connect to the QCD vacuum structure, the Hagedorn temperature and colour deconfinement as encapsulated in the new buzzword – quark–gluon plasma, the strongly-interacting colour-charged many-body state of quarks and gluons. Moreover, there is a wealth of numerical lattice results that accompany these developments.

I find no key word for this in the index of Quigg’s book, although there is mention of “confinement” (p336ff). On page 340, a phrase-long summary mentions the temperature of a chiral-symmetry-restoring transition (from what to what is not stated) that characterizes the lattice QCD results seen in figure 8.47 on p342. This one-phrase entry is all that describes in my estimate 20% of the experimental work at CERN of the past 25 years, and the majority of particle physics at Brookhaven for the past 15 years. In this section I also read how vacuum dielectric properties relate to confinement. I know this argument from Kenneth Wilson, as refined and elaborated on by TD Lee, and the lattice-QCD work initiated by Michael Creutz at Brookhaven, yet Quigg attributes this to an Abelian-interaction model that I did not think functioned.

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The author, renowned for his work addressing two-particle interactions, represents in his book the traditional particle-physics programme as continued today at Fermilab, where the novel area of QCD many-body physics is not on the research menu, though it has come of age at CERN and Brookhaven. One can argue that this new science is not “particle physics” – but it is definitively part of “gauge theories of strong interactions”, words embedded in the title of Quigg’s book. Thus, quark–gluon plasma, vacuum structure and confinement glare brightly by their absence in this volume.

Looking again at both books it is remarkable how complementary they are for a *CERN Courier* reader. These are two excellent texts and together they cover most of modern QFT and its application in particle physics in 1000 pages at an affordable cost. I strongly recommend both, individually or as a set. As noted, however, the reader who purchases these two volumes may need a third one covering the new physics of deconfinement, QCD vacuum and thermal quarks and gluons – the quark–gluon plasma.

● Johann Rafelski, University of Arizona.

Neutrinos in High Energy and Astroparticle Physics

By José W.F. Valle and Jorge C. Romão

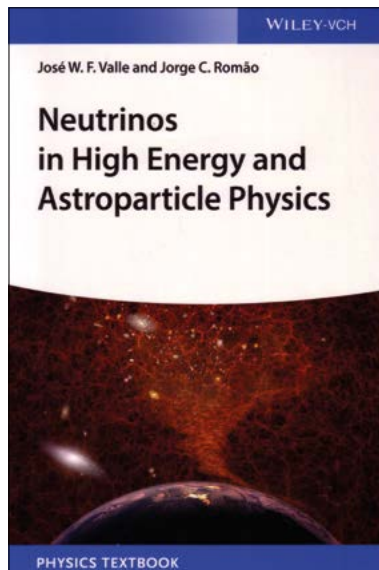
Wiley-VCH

Paperback: £75 €90

Also available at the CERN bookshop

Neutrinos have kept particle physicists excited for at least the past 20 years. After they were finally proved to be massive, two mass-squared differences and all three mixing angles have now been determined, the final remaining angle, θ_{13} , in 2012 by the three reactor experiments: Daya Bay, RENO and Double Chooz. As neutrino masses are expected to be linked intimately to physics beyond the Standard Model that can be probed at the LHC, and as neutrinos are about to start a “second career” as astrophysical probes, it seems a perfect time to publish a new textbook on the elusive particle. The authors Jose Vallé and Jorge Romão are leading protagonists in the field who have devoted most of their careers to the puzzling neutrino. In this new book they share their experience of many years at the forefront of research.

They begin with a brief historical introduction, before reviewing the Standard Model and its problems and discussing the quantization of massive neutral leptons. The next three chapters deal with neutrino oscillations and absolute neutrino masses – the mass being one of the fundamental properties of neutrinos that is still unknown. Here the



authors give a detailed discussion of the lepton-mixing matrix – the basic tool to describe oscillations – and seesaw models of various types. An interesting aspect is the thorough discussion of what could be called “Majoraneness” and its relation to neutrino masses, lepton-number violation and neutrinoless double beta decay – for example, in the paragraphs dealing with the Majorana–Dirac confusion and black-box theorems, a point that is rarely covered in text books and often results in confusion.

Next, the book discusses how neutrino masses are implemented in the Standard Model’s $SU(2) \times U(1)$ gauge theory and the relationship to Higgs physics. This is followed by a detailed treatment of neutrinos and physics beyond the Standard Model (supersymmetry, unification and the flavour problem), which constitutes almost half of the entire book. Here the text exhibits its particular strength – also in comparison to the competing books by Carlo Giunti and Chung Kim, and by Vernon Barger, Danny Marfatia and Kerry Whisnant, both of which concentrate more on neutrino oscillation phenomenology – by discussing exhaustively how neutrino physics is linked to physics beyond Standard Model phenomenology, such as lepton-flavour violation or collider processes. The inclusion of a detailed discussion of these topics is a good choice and it makes the book valuable as a textbook, although it does make this part rather long and encyclopedic. Another strong point is the focus on model building. For example, the book discusses in detail the challenges in flavour-symmetry model building to

accommodate a non-zero θ_{13} , and the deviation of the lepton-mixing matrix from the simple tri-bi-maximal form.

The authors end with a brief chapter on cosmology, concentrating mainly on dark matter and its connection to neutrinos. While this chapter obviously cannot replace a dedicated introduction to cosmology, a few more details such as an introduction of the Friedmann equation could have been helpful here. In general, the treatment of astroparticle physics is shorter than expected from the title of the book. For example, the detection of extragalactic neutrinos at IceCube is not covered – indeed, IceCube is only mentioned in passing as an experiment that is sensitive to the indirect detection of dark matter. Also leptogenesis and supernova neutrinos are mentioned only briefly.

The book mainly serves as a detailed and concise, thorough and pedagogical introduction to the relationship of neutrinos to physics beyond the Standard Model, and in particular the related particle-physics phenomenology. This subject is highly topical and will be more so in the years to come. As such, *Neutrinos in High Energy and Astroparticle Physics* does an excellent job and belongs on the bookshelf of every graduate student and researcher who is seriously interested in this interdisciplinary and increasingly important topic.

● Heinrich Päs, TU Dortmund, and Sandip Pakvasa, University of Hawaii.

Books received

Canonical Quantum Gravity: Fundamentals and Recent Developments

By Francesco Cianfrani et al

World Scientific

Hardback: £84

E-book: £63

Also available at the CERN bookshop



This book aims to present a pedagogical and self-consistent treatment of the canonical approach to quantum gravity, starting from its original formulation to the most recent developments in the field. It begins with an introduction to the formalism and concepts of general relativity, the standard cosmological model and the inflationary mechanism. After presenting the Lagrangian approach to the Einsteinian theory, the basic concepts of the canonical approach to quantum mechanics are provided, focusing on the formulations relevant for canonical quantum gravity. Different formulations are then compared, leading to a consistent picture of canonical quantum cosmology.