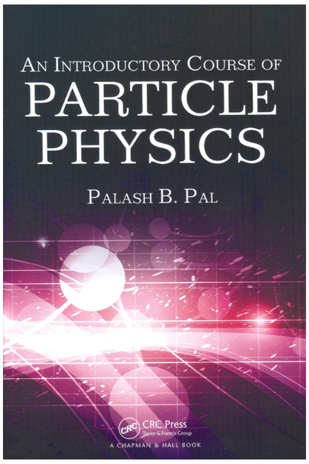


An Introductory Course of Particle Physics. Palash B. Pal. CRC Press, Taylor & Francis Group, 6000 Brokou Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742, USA. 2015. xxviii + 788 pp. Price not mentioned.

The Standard Model is the fundamental theory in terms of which almost every phenomenon in the Universe is expected to be understood. There are of course a few notable and important exceptions to this dramatic claim – gravitational phenomena, dark matter/energy, matter–antimatter asymmetry, neutrino masses, emergence of various macroscopic phenomena, etc. which remain as puzzles that suggest that physics is certainly not a finished business. But by and large, it is fair to say that theoretical physicists who are interested in the fundamental laws of nature, hold the Standard Model as the state-of-the-art in our understanding of the high-energy frontier. Its predictions have been spectacularly confirmed in experiments so far, culminating in the recent discovery of the Higgs boson at the Large Hadron Collider (LHC) in Geneva. The discovery of the Higgs boson has given a certain finality to the Standard Model: no matter what we discover at the energy scales that lie beyond, phenomena that happen below an energy of about a tera electronvolt (TeV) will likely forever be understood in terms of the Standard Model.

The book under review on particle physics is a pedagogical, thorough and enjoyable introduction to this fascinating subject. It is also very timely, because the discovery of the Higgs boson and the completion of the bestiary of expected fundamental particles in the Standard Model, happened only about two years ago. The author Palash Pal provides a carefully written textbook on the Standard Model in the post-LHC era, at the level of a graduate-level course. The book is aimed at a reader with a knowledge of quantum mechanics and perhaps a (rudimentary) acquaintance with quantum field theory, and leaves him/her with a working knowledge of our current understanding of particle physics. The paradigmatic target audience would be graduate students in high-energy physics or advanced undergraduates, but I think the leisurely pace of the book is ideally suited for self-study as well. Theorists and phenomenologists with an interest in particle physics would also do well to acquire a copy.

The book starts off at a fairly basic level, making it accessible to a broad audience. After a discussion of the scope of particle physics, there are introductory chapters on relativistic kinematics, group/representation theory and quantum field theory. There is a chapter on perturbative quantum electro dynamics, after which there is a detailed discussion on discrete symmetries that is split over two chapters. After $SU(2)$ isospin is introduced, the book takes a diversion into an overview of experimental particle physics before going into a thorough discussion of $SU(3)$ flavour. Non-Abelian gauge theories are introduced gently, and then attention is specialized to quantum chromo dynamics (QCD) with discussions on asymptotic freedom, lattice gauge theory, confinement and the QCD vacuum. The next chapter concludes the basics of the strong interaction sector with a discussion on deep inelastic scattering. In the ensuing four chapters a thorough introduction to the weak sector is presented, starting with Fermi theory. Symmetry breaking and the electroweak interactions of leptons and hadrons complete the description of what constitutes the Standard Model. The next chapter deals with some of the basic features of the Standard Model – among other things, chiral symmetry breaking and anomalies are discussed in detail. Custodial symmetry, loop corrections and discussions of the Standard Model bosons (with emphasis on the Higgs) form one chapter. The next three chapters are more phenomenological in nature. Heavy quark flavour physics and CP-violation are discussed in detail; a thorough discussion of neutrino physics in and beyond the Standard Model follows. The book concludes with some semi-qualitative comments on beyond the Standard Model (BSM) ideas like grand unified theories (GUT), supersymmetry, string theory and others. There are ten appendices with various details – the one on spinors seemed especially useful.

Problems are sprinkled throughout, some of which are solved in an appendix. They are often not heavy-duty computation-oriented, and not even necessarily too tricky, but work as an excellent way to test one's understanding of the subject matter. As a self-taught student of particle physics from an originally engineering background, the present reviewer greatly appreciated the level at which the problems were pitched. The proof of Schur's lemma in exercise 4.8 is a perfect example of the simple, yet practical flavour of the exercises. Overall, the book itself has a hands-on, practical feel to it – the material is presented in an empowering way. It is well worth the time of an aspiring young high-energy theorist/phenomenologist to work through it cover to cover. The promise of expertise in the current state-of-the-art of (non-speculative) particle physics awaits.

One of the salient features of the book is that it manages to strike a good balance between introducing too little quantum field theory (QFT), and turning into a field theory textbook. This is refreshing because many of the introductory books on particle physics that are currently available in the market adopt the pedagogical philosophy that in any course on particle physics, one should under-emphasize field theory as much as we can. This is supposed to make it easier for the students because field theory is a difficult subject. However, from my experience teaching particle physics, I have found that this is not quite true, and that some amount of field theory in fact makes things more comprehensible. Of course, there are some other particle physics books that delve fairly deep into field theory, but (at least in the opinion of the present reviewer) are too quick to do a thorough job of their undertaking. The focus of the book is clearly on particle physics with a phenomenological outlook, but it includes a self-contained introduction to the relevant aspects of field theory to enable a beginning student to grasp the method behind the madness. There are introductory sections on group theory and QFT, and they contain carefully chosen material and careful explanations.

Later in the text Pal's approach to field theory is decidedly that of a phenomenologist; so he does not get swamped in half-cooked discussions on too many 'theoretical' matters, but he does have clear discussions of instantons, anomalies, large-N theories and lattice gauge theory (among other things).

The biggest strength of this book is its pedagogical clarity. It comes in superficially intimidating at around 800 pages, but I think this should not deter the reader from taking it on – in many ways the size is an artifact of the care that is paid in the clarity of presentation, a thinner book would have been harder and longer to read. Another related feature of the book is that the computations are often done in enough detail, so that one can often read through the book to a degree without getting bogged down in too much pen and paper. Apart from the pedagogical value for novices, the later chapters of the book are interesting for active high-energy physicists as well (at least those who are not too closely involved with particle phenomenology, like the present reviewer). The discussions on loop effects, custodial symmetry, Peskin–Takeuchi parameters, CP violation and various aspects of neutrinos stood out as particularly clarifying.

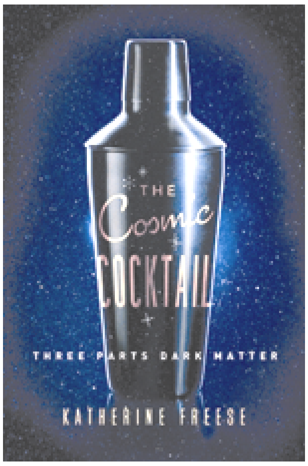
Now that the review of the subject matter is out of the way, let me talk about a few stylistic features of the book that I found jarring. One is the typesetting – there are way too many font-types inside the book, which gives some pages a rather dog's breakfast-like look. But the author is clearly aware of the outrage his typesetting idiosyncrasies cause among his colleagues (he says as much in one of the paragraphs in the preface). I am also one of those who is outraged by this – in my defence, it is not so much the specific fonts that I found irksome, but the bad *feng-shui* that they produce on a page when mixed together (seemingly) erratically. The printing and production of the book is well done by CRC Press, so it does somewhat compensate for the chaotic fonts.

Another (minor) personal peeve that I have with the book is that at various points, it manages to convey a certain adoration that goes beyond mere respect towards Lincoln Wolfenstein, Pal's Ph D advisor. Clearly Wolfenstein is a great physicist, but pedestalizing our (obviously worthy) idols, gives the impression that the only place for us to stand, is below. In a world where fundamental theory is increasingly global, it is perhaps more important to humanize the greats – not the least because the heroes of the last generation often belonged to a different race, place, sex or caste, and they are often already larger than life in the eyes of an aspiring student.

But these are all minor nits to pick – as a textbook, Palash Pal's tome on particle physics is accessibly written for serious beginning students, and is a great addition to the bookshelves of seasoned scientists interested in the phenomenological foundations of the Standard Model.

CHETHAN KRISHNAN

Center for High Energy Physics,
Indian Institute of Science,
Bengaluru 560 012, India
e-mail: chethan@cts.iisc.ernet.in



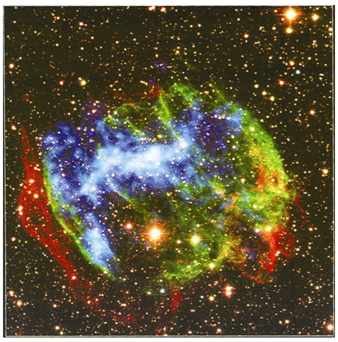
The Cosmic Cocktail: Three Parts Dark Matter. Katherine Freese. Princeton University Press, 41 William Street, Princeton, New Jersey 08540, USA. 2014. xi + 250 pp. Price: US$ 29.95.

Dark matter is an enigma of modern astrophysics. About a third of the total mass energy of the universe is believed to be made up of something that gravitates but does not shine. Another two thirds is thought to be composed of yet another intriguing substance called the dark energy. The type of matter that we normally encounter constitutes a tiny 4%.

Are these ideas for real, or do they represent a desperate attempt to explain the observations with incomplete or wrong theories? In this candid book, Freese tackles these questions, beginning with the story of the research on this topic that she interweaves with her personal narrative. She was one of the first physicists to think about possible ways of detecting dark matter particles, and her story provides an interesting backdrop for the history of dark matter theories and experiments.

Although she has been involved in many aspects of developing theoretical models of dark matter particles, and in thinking of extraordinary way of detecting them (one using DNA strands!), her narrative is remarkably forthright. At the end of the book, after describing the present state of confusion among the scientists, she asks: 'Is it possible that dark matter and dark energy don't exist? Could scientists be missing something fundamental? Perhaps an entirely different way of looking at the world will replace the need for these invisible pieces of the Universe.'

Currently, there are a number of ongoing experiments around the world, trying to look for the elusive dark matter particles. No one yet knows what properties (even mass) these particles may have, but as Freese's account tells us, there are some broad ideas. One is to use large particle accelerators, such as the one in CERN that discovered the Higgs particle, and hope that particle collisions would create some dark matter particles. Another idea is to use detectors of some special nuclei which may detect the dark matter particles that are swarming around the solar system in this part of the Milky Way. As the Earth goes around the Sun, these detectors are likely to show an annual modulation (although tiny in magnitude) of the detection rate. Freese was one of the first people to predict and characterize such an expected modulation. An Italian experiment claims to



A supernova remnant.