From Griffiths to Peskin: a lit review for beginners

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a.k.a. “How to get started learning QFT as an undergraduate.”

**5 Jan 07:** Slight updates (added more details) to a few of the reviews, and an added caveat.

Quantum Field Theory (QFT) plays a key role in all branches of theoretical physics. For students interested in high energy theory, exposure to QFT at any early stage is slowly becoming the standard for top American graduate schools. This is already the case for the Mathematics Tripos at Cambridge.

However, the ‘standard’ American undergraduate physics curriculum doesn’t typically encourage Quantum Field Theory, nor do smaller liberal arts college regularly offer QFT courses. It is often expected that a student will take a second year of ‘graduate’ quantum mechanics before taking QFT.

An inspired student with adequate background should be able to take quantum mechanics in his/her second or third year and then progress directly to a ‘real’ QFT course with a bit preparation, without going through the rigmarole of a year-long graduate quantum mechanics course.

Instead, I present a rough guide to pedagogical QFT literature so that a motivated student can prepare for a graduate-level QFT course or a get started with a self-study during the summer after his/her undergraduate quantum mechanics course. As a someone who was in this position in the not-too-distant-past, I hope some personal experience with the pros and pitfalls of the listed texts will be helpful for other other students interested in doing the same.

**Caveat:** My mini-reviews of the texts below are all meant for students with no previous background of QFT who are looking for textbooks and rough directions for an independent study. *All*the texts mentioned have their merits, but *some*of the books are much better suited for beginners than others. And, as always, there’s a degree of individual taste involved in picking a good text.

*Details for all textbooks mentioned are in the references section at the end.*

**Assumed Prerequisites**

* A course on Lagrangian and Hamiltonian mechanics. Pick your favorite text. The latest edition of Goldstein is the gold standard, but something at the level of Marion & Thornton will do.
* Some familiarity with classical field theory which may have been covered in the above mechanics course. No need to go into too much depth, the first few sections of Zee or the relevant chapter of Carroll’s GR book will do.
* Facility with special relativity at slightly better than chapter 12 of Griffiths’*An Introduction to Electrodynamics*. One should be comfortable with indices and four vectors. It’s probably overkill, but I thought Carroll’s GR book was a good introduction to four-vectors.
* A quantum mechanics at the level of Griffiths’ *An Introduction to Quantum Mechanics*. It’s key to understand the raising/lowering ops for the harmonic oscillator. A solid understanding of the Born approximation will help, as well.
* The equivalent of a “mathematics for physicists” course that covers Fourier decomposition and enough complex analysis to calculate a contour integral. No need for any of the fancy machinery, but one can’t afford to be intimidated by momentum-space representations of 4D delta functions or the calculation of residues.

**‘Extra Credit’ Prerequisites**

* Basic group theory, representation theory, and the Lorentz/Poincare groups. The Poincare group is probably a bit removed from the undergraduate curriculum, but it make things easier when dealing with spinors and the Dirac equation.
* Green’s functions. A slightly more advanced topic covered in a proper PDE or in a Jackson E&M course. Familiarity with the heuristic idea will clarify some of the mathematical manipulation that can confuse beginning quantum field theorists.

Ideally a student with a strong background could take the analytical mechanics course, electrodynamics, and the mathematical physics course early on. With a solid mathematical background, quantum mechanics can often be taken concurrently with electrodynamics. A first course in general relativity would provide all the special relativity required as well as giving some geometric perspective of gauge theories. (In principle a student can fit all of this in by the end of their sophomore year.)

**A review of the literature for beginners**

**Peskin, *An Introduction to Quantum Field Theory***. For over a decade this has been the standard in QFT pedagogy. It has everything a student could want presented coherently. The style is geared towards calculations, which makes it a handy reference. **What I like about it:** The book works remarkably well for a meticulous line-by-line study. If one understands every sentence in the first *n*chapters, then the (*n+1*)st chapter is written at just the right level. More advanced topics are covered very well, including a very good treatment of the renormalization group (Peskin was a student of Ken Wilson). Conceptual chapters that begin each part are especially well written. **What confused me the first time I read it:**It’s easy for a beginner to get lost in the details and lose track of which derivations are really important and which are just mathematical machinery. While everything is built up very methodically, it’s hard to get a sense of the ‘big picture’ especially in the first four chapters. **Conclusion:**Every QFT student needs this book… but absolute beginners may not find this the most user-friendly text and would benefit from additional references. Either way, I would suggest basing one’s study on Peskin with well-selected auxilliary reading.

[**Zee, ASTI lectures**](http://www.asti.ac.za/lectures.php). Tony Zee’s lectures at the African Summer Theory Institute are an excellent ‘preview’ of quantum field theory. Not to mention they’re quite enjoyable to watch (as are the other lectures in that set). **What I like about it:** It’s a really friendly introduction to the subject. **What confused me the first time I watched it:** Well, not really ‘confused;’ don’t expect too much meat out of the lectures. They’re at a very low level. **Conclusion:** If Peskin is the main dish, then Zee’s ASTI lectures are the little piece of bread they serve while you’re looking at the menu.

**Zee, *Quantum Field Theory in a Nutshell***. Zee’s textbook is one of the most physically motivated introductions to QFT. Prior to this book it was unheard of suggest a ‘conceptual’ course in quantum field theory. Peppered with anecdotes and flavored with a playful writing style, *QFT in a Nutshell* is the entree of the meal. It’s not meant to be as filling as Peskin, but does a perfect job as a first course. After Zee you won’t be calculating two-loop corrections, but you will understand what they are. **What I like about it:** The writing style and presentation of topics is nearly Feynman-esque in its clarity and pedagogy. It is written at just the right level for students who want to build up a solid conceptual understanding. Bonus topics (everything past Part V of the book) will keep Zee a valuable reference for ‘first looks’ at topics like condensed matter field theory, GUT theories, SUSY, and gravity as a gauge theory. **What confused me the first time I read it:** In any QFT course, students must learn QFT twice: once using the canonical formalism and once using the path integral formalism. Peskin teaches them in that order. Unfortunately Zee teaches in the opposite order. This makes it difficult to synchronize a reading of Peskin and Zee until one has done at least few chapters of one or the other. (The canonical formalism follows from quantum mechanics more readily, while the path integral formalism is more physically transparent.) **Conclusion:** Don’t expect to learn all the nitty gritty details from Zee, that’s not the point of the book.*QFT in a Nutshell* is everything you’d expect from a good friend: it will hold your hand, make you laugh, and “isn’t afraid to lie to you [for your benefit],” as one professor remarked. To bridge the conceptual gap between Griffiths and Peskin, Zee hits the spot quite well. It’s just unfortunate that the order of presentation put the two slightly out of phase. If one has plenty of time and is in no rush to calculate diagrams, consider reading all of Part I of Zee, especially the first parts and section I.8 where he relates it to the canonical presentation that Peskin begins his book with. This will bridge Zee’s physical explanations with Peskin’s technical explanations.

**Griffiths, *Introduction to Elementary Particles.*** The main difficulty in preparing for QFT is that a student who has just finished taking a first course in quantum mechanics doesn’t necessarily have any idea what is important to learn and why. The best way to motivate and frame one’s study of quantum field theory is to go through the first seven chapters of Griffiths’ *Introduction to Elementary Particles*, which is at just the right level for a student who has just finished Griffiths’ quantum mechanics text. This reading is very accessible and can be completed rather quickly. Chapter 2 provides a glimpse of the Standard Model and Feynman diagrams. Chapter 3 reviews most of the special relativity that you’ll need. Chapters 4 and 5 on symmetries and bound states can be skipped. Chapter 6 begins to reveal the machinery of QFT, explaining how to calculate simple cross sections and Feynman rules. 6.2 is especially important as writing down Feynman rules is the “punchline” of chapter 4 of Peskin. Chapter 7 explains how this all works for fermions, including an introduction to the Dirac equation that is excellent preparation for the analogous chapter in Peskin. **What I like about it:** Griffiths *Introduction to Elementary Particles* is written at exactly the level of a student who has just completed his quantum mechanics book. It will paint a [somewhat outdated] picture of particle physics and motivates why one needs to slog through the first four chapters of Peskin. (And trust me, if you get in over your head in calculations, you’ll need all the motivation you can get.) Chapter 6 and 7 should be required reading before starting Peskin as it gives an accessible description of Dirac spinors and Feynman diagrams. Slogging through chapter 4 of Peskin will make more sense if one already knows what ‘the answer’ will be at the end of the day. **What confused me the first time I read it:** This isn’t a QFT book. At best it’s a glimpse of the calculations that QFT will formalize. **Conclusion:** If you’re coming from a Griffiths *Introduction to Quantum Mechanics* background, this is required reading over the summer before taking QFT. If Peskin’s text is the main course, and Zee’s ASTI lectures/QFT text are the *pane* and starter respectively, the what’s Griffiths’ *Introduction to Elementary Particles*? It was lunch. Yesterday.

**Greiner, *Field Quantization.*** Greiner is the German counterpart to Landau & Lifschitz. His multivolume course on theoretical physics is slowly making its way into English translations. They’re remarkable in at least two respects: (1) the number of worked examples included in every volume, (2) the page layout. Each Greiner text has copious worked examples so that students can ‘learn by doing.’ Examples highlight key ideas or prove important lemmas. Students, of course, should attempt the examples without looking at the solutions right away. The layout provides very large margins which invite the student to jot down notes and thoughts as they read (a proper QFT book should be covered in multiple layers of notes). *Field Quantization*is no exception to these. **What I like about it:** Greiner fills in a lot of the nitty-gritty details left out by Peskin. It’s easy to read particular sections relatively independently. The examples are a huge plus as you won’t find many worked examples in any other QFT text. Greiner also takes the time to spell out important derivations. **What confused me the first time I read it:** Greiner takes his time getting to Feynman diagrams and his attention to detail means the pace of his book is much slower than any of the other books listed here. **Conclusion:** I’ve found Greiner an indispensable reference. It’s easy to pick it up with a specific question and look up a particular worked example or section. As an independent text, unfortunately, it’s difficult to get a sense of the ‘big picture.’

**Weinberg, *The Quantum Theory of Fields, Vol I.***One of my favorite Zee quotes (from his ASTI lectures, I believe) is that, “The only person who can understand Weinberg is Weinberg.” The three volume set is a treasure trove of insight into QFT by one of the greats. Unfortunately, it’s nearly unreadable for someone who hasn’t studied QFT before. Even the typesetting, with its super-curly letters, is opaque. **What I like about it:** This is QFT taught by someone who’s spent a lot of time thinking about it (and contributing significantly to its development!). It’s full of lots of really deep insights. **Why I was confused:**… but for someone with no prior QFT background, extracting knowledge from Weinberg is like pulling teeth. His first volume approaches the subject from a different direction than any other text, making sure to take time to point out several subtleties along the way. A proper reading requires respectable background of representation theory. **Conclusion:** The first chapter is a good read as it presents a historical introduction to QFT. Otherwise, one can hold off on Weinberg until after finishing Peskin. I’ve started using Weinberg as a reference for particular topics (after some background), and have found his books very useful in this respect.

**Ryder, *Quantum Field Theory, 2nd ed.*** Ryder is a very good introductory text that fits in several tangential topics without sacrificing overall flow. **What I like about it**: For the most part it’s accessible and informative. Several of the ‘tangential’ topics are especially well presented for a beginner, though they only give a taste. It also includes the best explanation of Noether’s theorem (with Greiner taking a close second place). **Why I was confused:** Ryder starts out by assuming a little bit of representation theory, which turned me off the first time I tried to read it. Also, I know it’s shallow, but was I the only one who would always forget what the bi-directional partial derivative symbol meant? **Conclusion:** Ryder didn’t really do it for me the first time around, but I enjoy reading bits of it for fun on the side. If you’re familiar with the Poincare group, you might consider reading Ryder as a main text.

**Tong,**[Lectures on Quantum Field Theory](http://www.damtp.cam.ac.uk/user/dt281/qft.html). David Tong’s lecture notes from his Part III QFT course roughly cover the first four chapters of Peskin. They’re effectively a set of Cliffs Notes for Peskin, highlighting the important bits and downplaying the less-important calculations. Extra emphasis on Noether’s theorem and working with creation/annihilation operators. **What I like about it**: these make an excellent road map for the first part of Peskin, almost tailor made. This is just what the doctor ordered if you find yourself getting lost reading Peskin. **Why I was confused:** … for once, I wasn’t. A few calculations are left as exercises, so don’t expect a free ride. **Conclusion:**Returning to a previous analogy, Tong’s lecture notes are the glass of wine that goes with the main course that is Peskin. They read quite well by themselves; I suspect a summer spent reading Griffiths-Zee Part I-Tong would be quite good preparation for a full-year Peskin-level course. One could also use Tong’s notes as a roadmap for the ‘important’ parts of Peskin.

**Other Books:**Bjorken and Drell was the standard textbook before Peskin. (The Peskin before Peskin, if you will.) Another oldie is Mandl and Shaw, of which I’ve heard the first edition is a better read than the second edition since it focuses on phi-fourth theory without the added complications of fermions. The point with these older books is that QFT did not really evolve into its present form until the 70s when Ken Wilson first described the physical significance of renormalization. It wasn’t until Peskin’s book that the renormalization group was treated properly in a modern text. Newer books also benefit in slightly more standardized notation and better typesetting. Among the post-Peskin crop of books worth looking into are Lahiri and Pal, Bailin and Love, Kaku, and Nair. (Actually, Kaku and Bailin & Love came out just before Peskin.) Lahiri and Pal is a ‘friendly’ introduction to basic calculations in QFT, while Kaku and Nair are more keen to present a wide range of ‘extra’ topics. Bailin and Love is a bit concise for my personal taste. Finally, the most recent QFT book is the one by Mark Srednicki. An [online preview copy](http://www.physics.ucsb.edu/~mark/qft.html) is available at Professor Srednicki’s website. I’m not familiar enough with any of these texts to give noteworthy commentary. But even if they don’t fit into one’s grand plans of self-study, they might be worth consulting in the library once in a while for that slightly-different perspective that clears up a confusing point here or there.

**Online resources:** I was originally hesitant to include these since I don’t have much experience with them, but for completeness are a few QFT resources online that may (or may not) be of interest to the beginning student:

* **Warren Siegel,**[*Fields*](http://insti.physics.sunysb.edu/~siegel/errata.html). This would be quite a tome if it weren’t published only on the arXiv. This well thought-out text with a novel mode of distribution takes an approach that is orthogonal to any of the aforementioned texts. I suspect that this is better read after a first look, and perhaps a second look, at QFT and related subjects.
* **‘t Hooft,**[*The Conceptual Basis of QFT*](http://www.phys.uu.nl/~thooft/lectures/basisqft.pdf). Suppose someone wrote a textbook at a level and style somewhere between Zee and Peskin. Now suppose someone else wrote a condensed version of that book. And for good measure suppose someone else further condensed that book into a section of the Elsevier *Handbook of the Philosophy of Science*. That’s what this seems like.
* **Coleman’s QFT course**. I don’t have a link, but there exist pdf copies of lecture notes from Sidney Coleman’s legendary QFT course. I’ve recently glimpsed through one copy and found them quite good. Rumor has it that there also exist video recordings of Coleman’s lectures that are locked away in a Harvard vault. (Want to hear an easy way to make YouTube *that*much more popular among physics students?)

**Additional Thoughts**

In fall of 2005 Stanford experimented with a one-quarter ‘undergrad QFT’ course taught out of Zee’s *Quantum Field Theory in a Nutshell*. While I thought this was a very good idea (especially paired with a ‘particle physics course’ that introduces tree-level calculations), it didn’t catch on and I do not know of any other universities that have tried similar coures.

With the texts above, the goal for a motivated undergraduate should be to read through chapter 4 of Peskin’s *An Introduction to Quantum Field Theory* over the summer following an undergraduate quantum mechanics course. Perhaps the best course of action would be to begin with the Griffiths *Elementary Particles* reading and jump into Peskin, supplemented by Zee and Greiner.

This requires significant individual preparation, but also allows such a student to jump into QFT as early as his/her third year, allowing the possibility of starting research in theoretical physics during his/her final year. By the way… for those who are skeptical about how much they can fit into a well-organized summer of reading, consider the [MSc. lecture courses at the Centre for Particle Theory](http://www.dur.ac.uk/cpt/graduate/lectures/) at Durham University. In particular, look at the Michaelmas lecture timetable. In four weeks the lecture course covers ‘introductory field theory’ and group theory. In the following four weeks, they cover QED, the Standard Model, and path integral QFT.

I don’t claim that my advice will be useful for everybody, but as a student who made the jump from Griffiths to Peskin in the not-so-distant past, I hope that my own successes, pitfalls, and hindsight may provide a rough guide for those who are eager to get started with QFT.

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