Physics 202a – Quantum Field Theory

Syllabus for Fall 2007

1 Official business

- Class times: Tu-F 12:30-2, Physics rm 229.
- Office Hours: to be negotiated, my office (97-306). Also by appointment.
- Contact info. Phone: 781-736-2865. Office: 97-306. Email: `albion@brandeis.edu`
- Course website: `http://people.brandeis.edu/ albion/202a/course.html`.

2 Course outline

There will be a continued emphasis on relations between particle physics and condensed matter/statistical physics.

1. Introduction – Why Quantum Field Theory? Particle creation and decay, relativistic and nonrelativistic QFTs.
2. Basics of QFT
   - Scalar field theories. Wave equations. Lagrangian and Hamiltonia description. Second quantization.
   - What do we want to calculate? Correlation functions, response functions, what's done in the lab.
   - Interacting field theories/perturbation theory. Wick's theorem, Feynman diagrams, loop expansion.
   - Feynman Path integrals and QFT, relations to "old-school" quantization, review of relations to stat mech.
   - LSZ and scattering
   - Other important fields: relativistic fermions, photons.
3. Radiative corrections, Renormalization, Effective Field Theories. Critical exponents and deviations from mean field theory.

3 Problem sets

Problem sets will be handed out every two weeks on Tuesdays and generally due at the beginning of class two weeks after the assignment is posted. I will not accept late assignments unless I am contacted *before the due date* with a valid reason (professional travel, family emergency, etc.)

4 Grading

Grading will be based entirely on the problem sets.

5 Office Hours and availability

Office hours to be negotiated.

If the times we set up do not work for you, or you want to discuss something less publicly, you can ask me by email or schedule an appointment by email or phone (email is best). You can also drop by my office if the door is open, and we can either talk then or (if I am swamped) set up a time when we are both free.

Again, if you want to talk about broader topics – physics in general, life at Brandeis, shopping for a research topic/thesis advisor, career possibilities/preparation, etc – please feel free to talk to me.

6 Expectations

The course is designed around the lectures, so while I won't grade on attendance, I strongly urge you to come to class. I will use the lectures to motivate material, and will be taking questions then, so you can get clarifications in real time (assuming I know the answer).

The problems in this class will sometimes be demanding, which is traditional in any course in quantum field theory. I expect students to *complete* the problem sets to the best of their abilities, even if the problems seem longer than expected. Sometimes it is just important to work through a hard problem.

You are strongly encouraged to discuss the problem sets with each other. By this I mean discussing what the question means, and what techniques and strategies you might use to solve them. I feel that physics is best learned socially, with your peers. However, it should go without saying that the solutions you present should be your own; you should have understood the solution and explained it yourself, in your own way. Simply copying other people's problem set solutions constitutes plagiarism. Evidence of such will be dealt with via the procedures outlined in the student's guide to their rights and responsibilities.

7 Reading List

The textbook for this class will be Mark Srednicki's "Quantum Field Theory". I will not be following it precisely and there will be additional material on the relationship between quantum field theory and statistical mechanics.

- Peskin and Schroeder, *An Introduction to Quantum Field Theory* – the required text, and on reserve. Next to Srednicki, this is one of the best pedagogical books I have found on quantum field theory from the particle physics point of view, and has become the standard. I find the presentation to be clear and straightforward. It is a serious, in-depth book and a useful reference. It goes much farther than I will, and the emphasis is different (*eg* it is weighted more heavily towards particle physics).

- Zee, *Quantum Field Theory in a Nutshell*. On reserve, and in most bookstores (even Harvard Books, last I checked). This books is quite clearly-written and unusually insightful, as one would expect from one of the masters of applications of modern QFT to condensed matter physics and particle physics. It is very modern and cuts through a lot of BS from the physics standpoint. The presentation is not rigorous, and it should be a supplement to a more throrough book like Srednicki or Peskin and Schroeder.

- Mandl and Shaw, *Quantum Field Theory*, on reserve. The edition has been revised, though it costs a pretty penny new. A lot of students like this book, and I found it useful when I took this course – it's slim, in paperback, basic, and very straightforward. As a primary text it's too old-fashioned for my purposes, especially when I hit renormalization, but you may find this quite useful for the first part of the course.

- Ryder, *Quantum Field Theory*, on reserve. A readable and fairly modern introduction to QFT, again from the particle physics point of view. I find it intellectually a bit light, and people who have read it more closely than I have found some serious mistakes, so caveat lector.

- Ramond, *Field Theory: a Modern Primer*. 1st edition on reserve, but I can't find the second edition which is better. The early chapters of this book are very nice indeed. It has a good intro to spinors and fermions, and an excellent doscussion of path integral techniques and perturbation theory, from a fairly modern point of view. Still, I find its treatment of renormalization to be very old-fashioned, but that's true of most treatments that you will find. Overall I think this is an excellent book to have around.

- Itzykson and Zuber, *Quantum Field Theory*, on reserve once the person I've recalled it from returns it. A classic of thoroughness and inscrutability. That said, it is very complete, and if you are serious about QFT from a particle physicist's perspective, you really should own this. Though I would try to find it used if at all possible, its insanely expensive.

- Zinn-Justin *Quantum Field Theory and Critical Phenomena*, on reserve once returned. An encyclopedic tome dealing with QFT as practiced in particle and statistical physics. A very good reference for lots of things, rather formal/mathematical and less useful to learn from.

- Weinberg, *The Quantum Theory of Fields, v. 1-III*. Vol. I,II on reserve. This is a modern classic by one of the masters (that would be the Weinberg that got the Nobel for the standard model.) It is not an introductory book, but it is a superb reference on any subject of field theory you need to know about and everybody should own the first two volumes. Vol. III is on supersymmetry, which is far beyond what we will cover.

- Abrikosov, Gorkov, and Dzyaloshinski, *Methods of Quantum Field Theory in Statistical Physics*. Criminally, not in the library, but it should still be available in a resonably-priced Dover edition. A classic, and *highly* worth owning. A somewhat old-fashioned treatment, but still useful and nice to read. Basically covers perturbative QFT for non-relativistic many-body theory.

- Fetter and Walecka, *Quantum Theory of Many-Particle Systems*, on reserve. Covers very similar ground as AGD; also a very nice book, though again rather dated, and now thankfully printed by Dover so you can afford it.ugh

  You might also find it useful to look at Cardy's *Scaling and renormalization in statistical physics*, and Chaikin and Lubensky's cond mat book.