Physics 222. Quantum Field Theory Three. Professor Michael Dine

Spring, 2011. Syllabus.

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Office hours: Tuesday, 10:00-12:00 (subject to change) or by appointment.

Course website: go to department website and click on Dine; follow link to Physics 222. Homework and solutions and handouts will be posted here.

Course Description:
Last quarter, those of you in Tom Banks's 218 course mastered the theory of renormalization, and between Physics 217 and 218, you should have a good understanding of QED and field theories with scalars and fermions. Our first priority in this quarter will be to understand the basics of the Standard Model. We'll start with an introduction to non-abelian gauge theories. After writing the classical theory, we'll turn to the Higgs phenomenon. This will allow us to write down the full Standard Model.

Apart from electrodynamics, all of the situations in which we encounter the physics of the Standard Model is quantum mechanical, so we will then quantize the theory. Here we will draw particularly on your experience in 218 with path integral quantization. The ghosts, mainly an oddity in QED, will be essential in non-abelian theories. After we write down the full Feynman rules, we will turn to QCD, and exhibit *asymptotic freedom*. This is what allow the computation of processes involving short distances (high momentum transfers) in the strong interactions; the flip side is that explains why the theory is strongly coupled at scales of order a Fermi, and how the features of the hadron spectrum emerge.

From this point, we will want to take at least two weeks to discuss features of the Standard Model. We will discuss the predictions of QCD for the total cross section in e^+e^- annihilation and the width of the Z particle. We will talk about other high energy processes: deep inelastic scattering, lepton pair production (the Drell-Yan process), and heavy quark physics (which will allow us to discuss both strong and weak interaction issues). How much time we spend on this will depend on your interests. Some of these topics could become topics for individual presentations.

At the moment, my inclination would be to have three homework sets during the first half of the semester, and a major presentation by each participant in the second half. I would assist with the presentations.

Note on the texts: The book by Dine is spectacular. More seriously, the text seeks to introduce the topics above, in a fashion that you can hope to master each topic quickly. In every case, simple, accessible examples are studied. There is invariably much that can be done to extend the breadth (hopefully not so much the depth) of knowledge in each area. I am of the "desert island" theory, i.e you should be able to reconstruct the basics of each topic without a big pile of books and papers nearby. As an example, anomalies are a mathematically rich topic, but most of the issues that theorists encounter can be understood in terms of one or two simple Feynman diagram and path integral calculations. Similar statements apply to instantons, monopoles and the like, and to the issues we will encounter in supersymmetric theories.

Books on Reserve:

1. M. Dine, *Supersymmetry and String Theory: Beyond the Standard Model.* A great book, but I won't insist you buy it. I will use it for some of the discussion later in the course, but will provide handouts when needed. I actually do recommend it as a compact discussion of much of the material in this course and beyond.

2. S. Weinberg, *Quantum Field Theory.* Something of an encyclopedia. Unlike Srednicki or Peskin and Schroder, not ideal for a first exposure to the subject, but contains many deep insights.

3. T. Banks, Quantum Field Theory – provides many insights into the topics we will discuss here. A short book, but one needs to do some work to get its full value.

4. J. Bjorken and S. Drell – a classic early text. The first volume's discussion of Feynman diagrams is still valuable. Much of the other material is somewhat dated, and has been superseded by the texts above.

5. Itzykson and Zuber: Another encyclopedic text. Has a number of useful, worked out Feynman diagram computations, and good discussions of a number of particular topics. Again, a bit hard to use as a first time text.

6. L. Brown, Quantum Field Theory: idiosyncratic, discusses a variety of topics not found in other books.

I will put other books on reserve from time to time as seems appropriate.

Homework, exams,etc: There will be a problem set about once per two weeks, at least for the first six weeks of the quarter. There will probably be a project in lieu of a final. By mid quarter, we'll want to discuss possible projects.

***Very* tentative Schedule; will be updated as quarter progresses. It is important to do the indicated reading.**

1. Week 1. A brief group theory review (many of you will get more group theory this quarter with Professor Haber). Non-Abelian gauge theories – classical theory Chapter 15 of PS

2. Week 2. The Higgs phenomenon. The full Standard Model. Quantization. Chapter 20 of Peskin and Schroder. Start Chapter 16.

3. Week 3. Quantization of Non-Abelian Gauge Theories (continued), mainly QCD. Asymptotic Freedom. Chapter 16 of Peskin and Schroder.

4. Week 4: Complete quantization. QCD phenomenology (Chapter 17)

5. Week 5: QCD Phenomenology (continued.

6. Week 6: Grand Unification (handouts; Dine textbook Chapter 6).

7. Week 7-10: Supersymmetry and supersymmetry dynamics (this is tentative). In first of these three weeks, we would learn how to write supersymmetric lagrangians and write a supersymmetric version of the Standard Model (MSSM). In week two, we would discuss the phenomenology of supersymmetric, including existing constraints (likely stronger by that week than today), the Higgs field in supersymmetry, and possible detection strategies, dark matter, and grand unification. In weak three, we would spend some time on the rich dynamics of the theories, and the features that allow one to make *exact* statements. Readings probably from my TASI lecture notes of this past summer. (Also Dine textbook)