Physics 295. Independent Study: Topics in Advanced Quantum Field Theory. Professor Michael Dine

Spring, 2010. Topics for Study/Meetings.

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Information will be available on my web site on the course marked 195.

Course Description:

Topics to cover:

1. **Weeks 1-3:** Unitarity in quantum field theory: spectral representations for Green's functions: an illustration of the amount of information contained in the correlation functions of a quantum field theory. A first encounter with ultraviolet and infrared divergences in quantum field theory. PS chapter seven, particularly. Here we will encounter the renormalization of the electric charge in QED, and the computation of the anomalous magnetic moment.

2. Renormalization in non-abelian gauge theories. Asymptotic freedom of QCD. High energy behavior of spontaneously broken gauge theories. Calculation through straightforward perturbative methods and using the background field method. Chapter 16 of PS.

3. **Weeks 4-5:** Renormalization and the renormalization group more generally. Chapters 10,11,12 of PS, selected sections. Some discussion of counterterm method, general theory of renormalization group.

4. Grand unified theories: an application of effective field theory methods, renormalization group.

5. **Weeks six-seven:** Some aspects of the Standard Model: Perturbative and Non-Perturbative Aspects of QCD. Chapter 3 of MD.

6. Anomalies in global and gauge symmetries. The Strong CP problem. Chapter 5 of MD

7. Instantons. Chapter 6 and 7 of MD

8. **Covered by Banks?** Semiclassical phenomena in quantum field theory: Magnetic monopoles, vortices. Chapters 6 and 7 of MD

9. **Weeks eight-ten:** Limitations of the Standard Model. The technicolor solution of the hierarchy problem. Chapter 8 of MD.

10. Supersymmetry: basics. Chapter 9 of MD

11. Supersymmetry: the MSSM, and its phenomenology. Chapters 10 and 11 of MD.

12. Supersymmetric Grand Unification. Chapter 12.

13. Supersymmetry Breaking: O'Raifeartaigh Models. Supergravity and gauge mediated models, including recent developments ("General Gauge Mediation"). Chapters 10,11 of MD.

14. Supersymmetric dynamics Chapters 13 and 14 of MD.

15. Dynamical Supersymmetry Breaking: ISS, Retrofitting. Chapter 14 of MD and supplements.

The goal is to leave you ready to conduct research in most of the topics of current interest in high energy theory.

Note on the texts: For basic field theory topics you have not yet covered, particularly renormalization, we will follow the presentation by Peskin and Schroder, though with some modifications (partly in the interest of time. 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. Peskin and Schroeder, *Quantum Field Theory* – this has been the "work horse" of quantum field theory textbooks for a number of years. It's treatment remains up to date. It is sometimes, perhaps, too thorough. E.g. it has more on renormalization theory than one can hope to cover in two quarters.

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. There will probably be a project in lieu of a final. By mid quarter, we'll want to discuss possible projects.