Phys. 772, Quantum Field Theory I, Fall 2018 (Xerxes Tata)

This class is the first semester of a two semester course on Relativistic Quantum Field Theory, the standard language for describing high energy phenomena. During the first term we will first see why we need QFT (i.e. why we need field dynamics as opposed to particle dynamics), and understand how to write down non-interacting field theories. Next, we will introduce interactions and see how to evaluate the S-matrix perturbatively. By the end of the term, you should – given the form of the interactions – be able to compute scattering cross sections and decay rates of elementary particles, and compare the results with empirical values.

During the second semester, we will go beyond lowest order perturbation theory (which introduces a host of new issues), and also develop non-Abelian gauge theories that are the bedrock of the Standard Model of particle physics. But more about this in Spring 2019.

Texts: Quantum Field Theory (Lewis Ryder) and Introduction to Quantum Field Theory (Michael Peskin and Daniel Schroeder). The latter will be the main text. These texts will be used as a guide. If you buy only one, choose Peskin and Schroeder. The topics are sufficiently advanced that it is worthwhile to look at several texts to gain a broader perspective. Here is a book-list to help out.

- Relativistic QM and Relativistic Quantum Fields (Bjorken and Drell)
- Quantum Field Theory (Mandl and Shaw)
- Relativistic Quantum Theory (Berestetskii, Lifschitz and Pitaevskii)
- Quantum Electrodynamics (Akhiezer and Berestetskii)
- Quantum Field Theory (Nash)
- Quantum Field Theory (Lurié)
- Relativistic Quantum Field Theory (Schweber)
- Quantum Field Theory (Itzykson and Zuber)
- Advaanced Quantum Mechanics (Sakurai)
- Quanatum Electrodynamics (Jauch and Rohrlich)
- Quantum Theory of Fields (Weinberg)
- Quantum Field Theory in a Nutshell (Zee)
- Quantum Field Theory (Srednicki)
- Quantum Field Theory and the Standard Model (Schwartz)

Prerequisites: Non-relativistic QM, Classical E and M, Classical Field Theory (basics of Lagrangian field theories; canonical co-ordinates and momenta; Poisson brackets; Noether's theorem)

Homework will be assigned regularly and graded. Please do these assignments in a timely manner even if you plan not to register for the class (This is the ticket price). You will not be able to learn unless you keep up with these assignments, and it will be a waste of time.

Grade: Based on HW assignments (2/3) and a final HW assignment (1/3) in which you will not be allowed to consult with anyone else.

Topics to be covered:

- The Klein Gordon Equation as a wave equation for relativistic QM;
- Spinor Reps. of rotation and Lorentz groups;
- The Dirac equation for the electron as a wave equation;
- Coupling the Dirac electron to electromagnetism;
- The failure of relativistic QM as a one-particle theory.

Introducing Quantum Fields:

- A quick review of classical field theory using Lagrangians (you should have seen this; else start studying it).
- Free quantized fields: scalar, spinor and E-M field.
- Interactions – the S-matrix (please review the interaction picture from NRQM).
- Perturbative calculation of the S-matrix
- Relation between the S-matrix and observables: cross-sections, lifetimes.
- Lowest order calculation of physical processes

In Phys. 773 (or time permitting) we will continue with higher order calculations and move on to idea useful for the development of the Standard Model. I do not know whether we will have the time to introduce functional methods which really should be part of the theory tool-kit. But life is short.

By the end of the first term you should be able to compute realistic physical processes to lowest order in perturbation theory and compare with data. The class will also be preparation for the development of the Standard Model.