Course Syllabus for Physics 8806.02 (Spring 2016)

Field Theory in Quantum Many-Body Physics

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The goal of this special topic course is to introduce the method of quantum field theory, and show how it can be applied to understand a quantum condensed matter system of many degrees of freedom. The effective field theory language becomes extremely powerful when dealing with a large number of particles that strongly interact with each other. It provides a natural description of emergent phenomena such as magnetism and superconductivity.

Starting from the path integral formulation, we'll discuss a number of phenomena in strongly correlated quantum many-body systems: such as magnetism, superconductivity and Kondo effect. In particular we'll focus on physics in one spatial dimensions, where many physical properties can be understood in a quantitative fashion. In addition to understanding these properties, we'll also discuss how to experimentally measure them via linear responses.

Instructor: Assistant Professor **Yuan-Ming Lu**

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Office Hours: by appointment only

Course Location: Caldwell Lab 135 or physics research building 2015

Course Time: Tuesday and Thursday 9:35AM - 10:55AM

Pre-requisites (recommended):

- Quantum Mechanics 2 (Physics 7502), "Modern Quantum Mechanics" by Sakurai or "Principles of Quantum Mechanics" by Shankar or similar textbooks
- Classical and Statistical Physics II (Physics 7602), Landau-Lifschitz or Pathria-Beale or "Statistical Physics of Particles" by Mehran Kardar or similar textbooks

Textbook:
There is no specific textbook for this course. Lecture notes and references will be given.

Main References:

- *Condensed Matter Field Theory* by Alexander Altland and Ben Simons (2nd Edition, Cambridge University Press, 2012)
- *Field Theories of Condensed Matter Physics* by Eduardo Fradkin (2nd Edition, Cambridge University Press, 2013)
- *Quantum Physics in One Dimension* by Thierry Giamarchi (Oxford University Press, 2004)

Other References:

- *Quantum Field Theory of Many-body Systems: From the Origin of Sound to an Origin of Light and Electrons* by Xiao-Gang Wen (Oxford University Press, 2007)
- *Introduction to Many-Body Physics* by Piers Coleman (Cambridge University Press, 2015)
- *Quantum Field Theory in Condensed Matter Physics* and *Quantum Field Theory in Strongly Correlated Electronic Systems* by Naoto Nagaosa (Springer-Verlag Berlin Heidelberg, 1999)
- *Scaling and Renormalization in Statistical Physics* by John Cardy (Cambridge University Press, 1996)
- *Field Theory of Non-Equilibrium Systems* by Alex Kamenev (Cambridge University Press, 2011)

Syllabus:

- Path integral for bosons, fermions and spins
- Superfluid and duality
- Hubbard model, magnetism and superconductivity
- Quantum magnetism and nonlinear sigma model
- Linear response theory and response functions
- Quantum Hall effect
- Bosonization and Luttinger liquid
- Renormalization group
- Disordered systems and Anderson localization
- Kondo problem and large-N expansion

Assignments:

Homework will be assigned roughly every week. Handout on Thursday, due next Friday. No late homework will be accepted.

A term paper is due by the end of the semester. A number of topics will be suggested and different student should choose different topics.

Grading: Homework => 50%; Term paper => 50%.