PHYS 664 Condensed Matter Theory: Many-Body Formalism (Spring 2018)

Instructor: Matthew Foster, BRK 303, matthew.foster@rice.edu, ext. 3922
Lectures: 9:25-10:40 AM T. Th., HBH 22
Office hours: 10 AM–noon F, 303 Brockman Hall

Textbook: There will be no required textbook. Possibly useful references include

- *Quantum Many-particle Systems*, Negele and Orland
- *Introduction to Many-Body Physics*, P. Coleman
- *Condensed Matter Field Theory*, Altland and Simons
- *Lectures on Phase Transitions and the Renormalization Group*, N. Goldenfeld
- *Quantum Field Theory and Critical Phenomena*, J. Zinn-Justin
- *Quantum Field Theory in Condensed Matter Physics*, A. M. Tsvelik
- *Quantum Phase Transitions*, S. Sachdev

(Approximate) Syllabus

1. Second quantization
2. BCS theory of superconductivity
   - Cooper instability
   - Reduced BCS Hamiltonian and mean field theory
   - Bogoliubov theory; topological superconductivity
3. Path integrals I: One particle
   - Real and imaginary time
   - Tunneling and instantons
4. Path integrals II: Many particles
   - Coherent states, Grassmann variables
   - Imaginary time boson and fermion path integrals
   - Application: Boson Hubbard model
5. Green's functions and response theory
6. Interacting fermions
   - Feynman diagrams
   - Self-energy and the quasiparticle concept
   - Large-N picture

- Collective modes

7. Phase transitions and renormalization group
   - Scaling theory
   - Perturbative RG
8. Disorder
   - Kubo formulae
   - Perturbation theory and semiclassical response
   - Quantum diffusion and weak localization

Additional/alternative topics, interest and time-permitting

1. Superconductivity: Landau-Ginzburg theory; Higgs mechanism
2. Non-equilibrium quantum dynamics
3. Luttinger liquids, abelian bosonization
4. Spin path integrals, non-linear sigma models, theta and WZW terms
5. Composite boson theory of the fractional quantum Hall effect
6. Conformal symmetry; AdS/CFT duality

Learning outcomes

1. Understand the field theoretic approach to low-energy, long-wavelength physics in many body systems
2. Master the application of key techniques including functional integration, mean field theory, linear response, and perturbation theory
3. Exposure to model systems including phonons, Heisenberg magnets, lattice bosons, and the Jellium model for fermions
4. Understand and apply key mathematical tools including Gaussian integration, diagrammatic combinatorics, analytical continuation

Grading: Homework 4-6 sets (100%).

Prerequisites: Quantum mechanics, solid state physics, and statistical mechanics. Relativistic quantum field theory is not required, although it might be helpful.

Any student with a documented disability needing academic adjustments or accommodations is requested to speak with me during the first week of class. Additionally, students will need to contact Disability Support Services in the Allen Center.

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