Syllabus

Physics 625 (Spring, 2017) — **Non-relativistic Quantum Mechanics**

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Course web-site: http://terpconnect.umd.edu/~galitski/PHYS625/
Office hours: Monday, 2:00 p.m. – 3:00 p.m., room PHYS 2330
Lectures: Monday, Wednesday; 12:30 p.m. – 1:45 p.m., room PHYS 1219

Summary

The purpose of this course is to provide a graduate-level introduction to quantum many-body physics and condensed matter physics. This will include an introduction to second quantization, Green's function formalism,Feynman diagrammatic technique, Kubo linear response theory, Fermi liquid theory, Bardeen-Cooper-Schrieffer theory of superconductivity, theory of phonons in solids, theory of disordered quantum systems (in particular, localization), topological phases, and path integral formalism.

Reading

- Al. Altland and B. Simons , "Condensed Matter Field Theory," 2nd Edition, Cambridge University Press (2010)
- A. A. Abrikosov, L. P. Gor'kov, and I. E. Dzyaloshinskii, "Quantum Field Theoretical Methods in Statistical Physics," Oxford (1965)
- G. D. Mahan, "Many-Particle Physics," Plenum (1990)
- N. W. Ashcroft and N. D. Mermin, "Solid State Physics," Saunders College Publishing (1976)

Homework: There will be, on average, one homework assignment every 2-3 weeks. The homeworks will be posted on the class page.

Exam: There will be (possibly) a mid-term exam and a take-home final exam.

Grading will be based on the cumulative score on all exams and homework.

Outline

1. Second quantization; Bogoliubov transformation
   - (a) Classical chain of oscillators; Acoustic and optical phonons
   - (b) Quantum chain of oscillators
   - (c) Quantum fermionic chain
   - (d) One-dimensional quantum spin systems; Non-local Jordan-Wigner transformation. New emergent degrees of freedom in many-particle systems
2. Many-particle Quantum Mechanics: Non-interacting classical and quantum gases; Boltzmann, Fermi, and Bose distributions
   - (a) Properties of a Fermi gas
   - (b) Properties of a Bose gas; Bose condensation
   - (c) Bogoliubov theory of a BEC
3. Towards Feynman diagrams. Elements of single particle-quantum mechanics (warm-up/reminder)
   - (a) Green's function of the Schrödinger equation
   - (b) Simplest example of the diagrammatic technique: a pictorial representation of the scattering amplitude in single-particle quantum mechanics
4. Feynman path-integral in single-particle quantum mechanics
   - (a) Path integral for spin
   - (b) Topological Berry's phases and Wess-Zumino terms
5. Methods of quantum field theory in condensed matter physics;
   - (a) Schrödinger, Heisenberg, and interaction representations; S-matrix
   - (b) Green functions in many-particle systems; Perturbation theory and Feynman's diagrammatic technique for interacting particles
   - (c) Physical meaning of Green functions; Spectrum of quasiparticles
   - (d) Two-particle Green's function; Self-energy function
6. Application of the Green's function formalism to electronic systems
   - (a) Friedel oscillations and the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction between magnetic impurities in metals
   - (b) Electron-phonon interaction; Polaron in the weak-coupling approximation; Self-energy and effective mass
   - (c) Anderson orthogonality catastrophe
   - (d) Peierls transition

7. Fermi liquid theory and elements of superconductivity

    (a) Landau Fermi liquid theory; Phenomenology and microscopic justification
    (b) Collective modes: Zero sound and plasmons in an electron gas
    (c) Instabilities in a Fermi liquid
    (d) Superconducting instability and Cooper pairs
    (e) BCS wave-function

8. Generalized susceptibility; Kubo's formula for linear response quantities

9. Topological insulators