Syllabus

Physics 625 (Spring, 2021) — **Non-relativistic Quantum Mechanics**

Lectures: Monday, Wednesday; 12:30 p.m. – 1:45 p.m., zoom lectures until in-person teaching resumes (them room PHYS 1219)
Instructor: Prof. Victor Galitski
Office: 4449 Atlantic Building and PSC 2270
e-mail: galitski@umd.edu
Phone: 301-405-6107
Course web-site: https://terpconnect.umd.edu/ galitski/PHYS625/index.html
Office hours: Wednesday; 2:00 p.m. – 3:00 p.m., by zoom until in-person teaching resumes (then PSC 2270)

Teaching Assistant: Masoud Arzanagh
TA's e-mail: masoudma@umd.edu

Zoom & course rules

- Please, join class on time. Late "arrivals" are disruptive, as I need to admit people from the waiting room.
- Please have your camera on (unless there is a poor connection) to have a more interactive experience.
- Ask questions, make suggestions, etc to make the learning experience more productive & fun.
- I will take attendance, which will play a role in your final grade. Please, make an effort to attend all lectures.
- Submit your homework before deadline.

Homework: There will be, on average, one homework assignment every two weeks.

Grading

- Homework: 60%
- Attendance: 40%

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, topological quantum matter, theory of phonons in solids, theory of disordered quantum systems (in particular, localization), and (time permitting) 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)

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
   (e) Bogoliubov mean-field theory of a Bose-Einstein condensate
2. Topological quantum matter
   (a) Introduction to topological classification of band structures; bulk-boundary correspondence
   (b) Berry phase in quantum mechanics
   (c) Topology in 1D: Su-Schrieefer-Heeger model, Kitaev-Majorana chain, Haldane spin chain
   (d) Jackiw-Rebbi modes on domain walls/solitons
   (e) Topology in 2D: Chern insulators and integer quantum Hall effect
   (f) Topology in 2D: Haldane model and Kan-Mele model of a time-reversal invariant topological insulators
   (g) Topology in 3D: weak and strong topological insulators, Fu-Kane method
   (h) Topology in time: Thouless pump and Floquet topological insulators
   (i) Introduction to intrinsic topological order: toric code model and string nets.
3. Elements of single particle-quantum mechanics (warm-up/reminder before Feynman diagrams)
   (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

   (c) Schrödinger, Heisenberg, and interaction representations; S-matrix

4. Methods of quantum field theory in condensed matter physics;
   (a) Green functions in many-particle systems; Perturbation theory and Feynman's diagrammatic technique for interacting particles
   (b) Physical meaning of Green functions; Spectrum of quasiparticles
   (c) Two-particle Green's function; Self-energy function
5. 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
6. Generalized susceptibility; Kubo's formula for linear response quantities
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. Electrons in a random potential
   (a) Averaging Green's functions over disorder
   (b) Boltzmann transport equation; Conductivity of a normal metal
   (c) Quantum diffusion; Weak localization
   (d) Dephasing mechanisms in electronic systems