PHYSICS 555 SOLID-STATE PHYSICS

Fall 2023

Monday, Wednesday, Friday 9:00 AM -- 9:53 AM, Room: B-131, Grad. Physics Bld.

Instructor: Dmitri Averin, dmitri.averin@stonybrook.edu

office hours: Wednesday, 3-5 pm, through skype; also by appointments.

Advisory prerequisites: basic knowledge of the graduate-level quantum and statistical mechanics

Textbook: Steven H. Simon ``The Oxford Solid State Basics'' (Oxford University Press, 2013)

Supplementary reading: David Vanderbilt ``Berry phases in electronic structure theory'' (Cambridge University Press, 2018)

Outline: This is the first part of a graduate course in solid-state physics. The goal is to introduce the basic ideas of solid-state physics and their applications to the topics of present-day interest, like two-dimensional materials and topological insulators. The course will roughly follow the established tradition to discuss mostly the single-particle aspects of solid-state physics (leaving the multi-particle phenomena for the second part) but elements of the BCS theory of superconductivity will also be included. The list of topics will mostly follow the textbook with addition of some of the more advanced/modern items:

- one-dimensional models of solids:
  - quantization of lattice vibrations, phonons: heat capacity and other properties;
  - electrons in a periodic potential, band formation for weak and strong potential, Bloch's theorem;
- semiclassical theory of free electrons in metals;
- quantum Hall effect;
- qualitative discussion of chemical bonding;
- symmetries of crystal lattices;
- reciprocal lattice, formation of electron energy bands;
- graphene;
- semiconductor physics and devices;
- elements of BCS theory superconductivity, Bogolyubov-de Gennes equations;
- superconducting tunneling, Josephson effect, superconducting qubits;
- topological insulators.

Grading will be based on attendance (35%), homework assignments (35%), and final exam (30%).

Student Learning Outcomes: Students who complete this course

- will have a basic understanding of the foundations of solid-state physics;
- should have a broad knowledge of current research topics in solid-state physics, including graphene structures and devices, topological insulators, superconducting qubits, and their sufficiently detailed understanding to be able to start working on research projects in these areas.
- should be able to do simple calculations within the BCS theory of superconductivity including the Bogolyubov-de Gennes equations for superconducting structures.

Student Accessibility Support Center statement:

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information go to the following website: https://ehs.stonybrook.edu//programs/fire-safety/emergency-evacuation/evacuation-guide-disabilities and search Fire Safety and Evacuation and Disabilities.

Academic Integrity statement:

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty members are required to report any suspected instance of academic dishonesty to the Academic Judiciary. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at:

http://www.stonybrook.edu/uaa/academicjudiciary/

Critical Incident management:

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, and/or inhibits students' ability to learn.

http://www.stonybrook.edu/uaa/academicjudiciary/