Solid state Physics

Physics 3715

2025 Fall

Class Times: Tuesday and Thursday 1:00PM to 2:15PM

Classroom: 103 Allen Hall

Prerequisite: Quantum Mechanics, Statistical Mechanics

Textbooks: (1) David Snoke, Solid State Physics, 2nd edition (2) Ashcroft and Mermin, Solid State Physics

Grading: 60% weekly homework, 40% final exam

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1 Learning Objectives

This course provides basic knowledge for students interested in condensed matter physics. After learning this course, students should be able to use quantum mechanics to model any solid-state material and have a basic understanding of the electronic structure and the corresponding physical properties. In particular, students should have a quantitative understanding of band theory (analytic understanding and numerical computation) and a qualitative understanding of strongly correlated physics beyond band theory. With this knowledge, students should be able to understand the main messages of most research papers on condensed matter physics.

2 Outline

1. Fundamental Concepts
   (a) Electrons and nucleus
   (b) Phases of matter at zero temperature and finite temperature
   (c) Fermi Dirac distribution
   (d) Kinetic energy vs Coulomb interaction

(e) Coupling to electromagnetic field

(f) Disorder

2. Electrons in a periodic potential

   (a) Lattice structures

   (b) Bloch theorem

   (c) Nearly free electron model

   (d) Tight-binding model

3. Physics of good metals

   (a) Typical band structures of good metals

   (b) Surface states

   (c) ARPES and STM

   (d) Semiclassical theory of transport

4. Physics of band insulators

   (a) Typical band structures of insulators

   (b) Exciton and disorder states

   (c) Semiconductor physics

5. Integer quantum Hall effect

   (a) Landau levels

   (b) Integer quantum Hall effect

   (c) Integer quantum Hall effect in graphene

   (d) Haldane model

6. Phonons and electron-phonon coupling

   (a) Phonons in insulators and metals

   (b) Second quantization of phonons and electrons

   (c) Electron-phonon interaction

7. Electron-electron interaction

   (a) Hatree-Fock approximation

   (b) Mott insulator

   (c) Origin of spin-spin interaction

8. Superconductivity

   (a) Cooper pairs

   (b) phenomenological theory of superconductivity

3 Academic Integrity

Students in this course will be expected to comply with the University of Pittsburgh' s Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam, including dictionaries and programmable calculators.

To learn more about Academic Integrity, visit the Academic Integrity Guide for an overview of the topic. For hands- on practice, complete the Academic Integrity Modules.

4 Disability Services

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412) 228-5347 for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.