Physics 3715
Solid State Physics
Fall 2018 (2191)

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Lectures: 1:00 – 2:15 pm Tuesdays and Thursdays, including finals week, 106 Allen Hall

Office Hours:

I will schedule a regular office hour (or more) if there is demand. It may suffice to operate informally. You can contact me before or after lecture, by phone, or by e-mail to set up an appointment. It is best to set up an appointment in advance rather than coming to my office and knocking on my door, since I may not be available. Also, if there is interest, we could set up a weekly session to discuss questions on the homework problems, lectures, etc. A good time for such a session might be immediately following the weekly coffee/doughnut hour on Wednesdays.

Course Objectives:

The overall objective of this course is to give each student knowledge of and ability to work with the basics (electrons and phonons) of solid state physics useful for their research and as background for advanced courses. The objective is achieved through lectures, reading, regularly assigned homework, and a term project culminating in a ten-page paper. As a result of the term project, in addition to exploring a topic in solid state of personal interest, the student will be able to perform library research and write a coherent, well-organized manuscript, including proper citation of sources, effective figures and tables, etc. The term project simulates the process of producing a manuscript for publication. The first draft is submitted. I read it and provide a “referee report”; then the student submits a revised manuscript.

The Course:

This is a one-term course on the basic ideas of solid state physics. The field is vast and very active. We will try to cover many of the important ideas, with examples, and possibly include some currently hot topics. A list of potential topics follows. We will certainly cover the topics appearing near the beginning of the list. We won’t get to all of them. Chapters in Ashcroft and Mermin which treat each topic (aspects of it, at least) are indicated in parentheses.

- Free electron models (Drude, Sommerfeld), with application to transport and thermal properties (1, 2, 3)
- Crystal structure (4, 7)
- Reciprocal lattice (5), scattering experiments (6)
- Electron band structure: Bloch’s Theorem (8), nearly free electrons (9), tight binding (10), $\vec{\boldsymbol{k}}\cdot\vec{\boldsymbol{p}}$ theory, notation, other methods (11), examples
- Semiclassical Model with applications to electron transport (12, 13)
- Boltzmann Equation and electron transport (16)
- Electron-electron interactions (17), volume and surface plasmons, density functional theory

- Surface Physics (18)
- Cohesive Energy (20)
- Phonons (22, 23, 24), elastic limit
- Thermal properties of solids, including specific heat (various chapters)
- Anharmonic Effects (25)
- Electron-Phonon Interaction (26)
- Optical properties (various chapters): dielectric functions, optical functions, excitons, polaritons, nonlinear optics, etc.
- Insulators, dielectrics (27)
- Ferroelectrics
- Semiconductors (28, 29), including the extrinsic case
- Defects (30)
- Magnetism (31, 32, 33)
- Superconductivity (34)

The chapters of Ashcroft and Mermin most likely to be emphasized in this course include 1, 2, 4, 5, 6, 8, 9, 10, 12, 13, 16, 17 (maybe), 22, 23, 25 (maybe), 27, 28, 29 (may run out of time before reaching these last three chapters).

The following topics are not discussed in Ashcroft and Mermin, but might be treated in lecture:

- Introduction to Density Functional Theory
- Introduction to Group Theory with Application to Solids
- Nanoscience, including Landauer-Büttiker Formalism
- Integer Quantum Hall Effect
- Berry Phase and Solids
- Topological Phenomena

Text: *Solid State Physics*, Neil W. Ashcroft and N. David Mermin (Brooks/Cole, 1976)

Reserve Books (Bevier Engineering Library, G-33 Benedum Hall)

1. *Solid State Physics*, Neil W. Ashcroft and N. David Mermin (Brooks/Cole, 1976) This is the textbook for the course.
2. *Introduction to Solid State Physics*, Charles Kittel (2005, 8th Edition) A classic textbook. It has been updated, most recently in 2005. Some people prefer earlier editions, particularly the fourth.
3. *Principles of the Theory of Solids*, J.M. Ziman (1972, 2nd Edition) Another classic text. The author has a distinct style, which you may find appealing.
4. *Solid State Physics: Essential Concepts*, David W. Snoke (2009) A new textbook by a member of the University of Pittsburgh Department of Physics and Astronomy, which covers both classic and modern topics.
5. *Condensed Matter Physics*, Michael P. Marder (2010, 2nd Edition) Treats a wealth of topics, including many of current interest.
6. *Solid State Theory*, Walter A. Harrison (1970) Detailed discussion of band structure calculations, etc. Harrison has written a number of related books.

7. *Electrons and Phonons: The Theory of Transport in Solids*, J.M. Ziman (1960) Classic treatise.

8. *Quantum Theory of Solids*, Charles Kittel (1963) Contains detailed treatments of classic topics in the theory of solids, generally at a higher level than will be covered in this course.

9. *Condensed Matter in a Nutshell* by Gerald D. Mahan (Princeton University Press, 2011) A new book which treats a wealth of topics, including many of current interest.

10. *Fundamentals of Condensed Matter Physics* by Marvin L. Cohen and Steven G. Louie (Cambridge University Press, 2016) This new book was written by two very well-known condensed matter theorists.
11. *A Quantum Approach to Condensed Matter Physics* by Philip L. Taylor and Olle Heinonen (2002) The organization and approach of this book is quite different from those of classics such as Ashcroft and Mermin, and Kittel.

12. *Advanced Solid State Physics* by Philip Phillips (2012, 2nd Edition) This modern book is more suited to a second course in solid state physics.

<u>Term Paper</u>:

In lieu of exams, the capstone experience for this course will be a term paper approximately 10 pages in length. The purposes are: 1) to give you an opportunity to explore in some depth a specific topic in solid state physics of interest to you and 2) to gain practice in writing a scientific paper, including proper citation of sources, use of figures and tables, etc. In consultation with the instructor, you will choose a topic in solid state physics or a recent or classic paper from the literature as your topic. Since another purpose is to give you the opportunity to develop some breadth, you are discouraged from choosing the specific topic of your personal research. Here’s an incomplete list of potential topics for your consideration:

Graphene, transition metal dichalcogenides
p-state pairing
d-state pairing
nanoscience, quantum dots, quantum wires
macroscopic quantum interference
electrical properties of nanotubes
glass
electrons and phonons in quasicrystals
polaritons
topological insulators, Majorana fermions in solids
impurities in semiconductors as quantum qubits
functional materials, oxides, ferroelectrics
large bandgap semiconductors
metamaterials
plasmonics
impurities and defects in solids

A tentative schedule (and allocation of credit) for the term paper follows:

1. Propose topic, with abstract: Thursday, September 27 (5%)
2. Submit outline with references/sources list (15%): Thursday, October 18

3. Submit first draft (50%): Thursday, November 15
4. Submit revised manuscript (30%): Thursday, December 6

Grading:

Your grade will be determined by your performance on the problem sets (approximately weekly) and the term paper. The weighting will be 50-50. If I develop clicker questions, the (small) associated credit will be included with the homework.

Courseweb Site:

There is a Courseweb site associated with this course. It can be accessed through your http://my.pitt.edu account. This site will be used to make important announcements and to make materials available such as homework assignments and solutions, and lecture notes. My tendency is to place everything but announcements under "Course Documents".

Student Opinion of Teaching Surveys:

Students in this class will be asked to complete a *Student Opinion of Teaching Survey*. Surveys will be sent via Pitt email and appear on your CourseWeb landing page during the last three weeks of class meeting days. Your responses are anonymous. Please take time to thoughtfully respond, your feedback is important to me. Read more about *Student Opinion of Teaching Surveys*.

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**.

Disability Statement:

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.

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Statement on Classroom Recording:

To ensure the free and open discussion of ideas, students may not record classroom lectures, discussion and/or activities without the advance written permission of the instructor, and any such recording properly approved in advance can be used solely for the student's own private use.