Physics 1374
Solid State Physics
Fall 2019 (2201)

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Lectures: 1:00 – 2:15 pm Tuesdays and Thursdays, 103 Allen Hall

Office Hours:

I will schedule regular office hours 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 of solid state physics. 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 explore the literature and write a coherent, well-organized manuscript, including proper citation of sources, effective figures and tables, etc.

The Course:

This course will cover some of the basic ideas of solid state physics. The field is vast and very active. The textbook, which is not lengthy, introduces many "classic" topics. Once we get through the book, we will use the remaining lectures to introduce other topics, including some which are currently active research fields. You will have the opportunity to choose a topic in solid state physics that interests you, explore it, write a short paper, and tell your classmates about what you learned.

A tentative course outline appears on the next page. The topics covered after we get through the textbook can be modified based on student interest.

Wk	Topic	Chapters	Date
1	Syllabus, Introduction to Course, Einstein Model for specific heat	1	Aug 27
	Debye Model for specific heat; Drude Model for electron transport	2 – 3	Aug 29
2	Sommerfeld Model for free electrons; Fermi-Dirac statistics	4	Sept 3
	Periodic Table; Binding in solids	5 – 6	Sept 5
3	Binding in Solids; Types of Matter	6 – 7	Sept 10
	Compressibility, Thermal Expansion, Sound; 1D Monatomic Chain	8 – 9	Sept 12
4	Vibrations of 1D Diatomic Chain	10	Sept 17
	Tight Binding Model in one dimension	11	Sept 19
5	Crystal Structure: Bravais Lattice and Basis	12	Sept 24
	Reciprocal Space; Brillouin Zone	13	Sept 26
6	X-Ray Scattering: Bragg and Laue Conditions	14	Oct 1
	Scattering Experiments (X-rays and neutrons)	14	Oct 3
7	Electrons in a Periodic Potential: Bloch's Theorem	15	Oct 8
	Insulators, Semiconductors, and Metals	16	Oct 10
8	Semiconductor Physics: Electrons and Holes, Statistics	17	Oct 15
	Semiconductor Devices: p-n junction and transistor	18	Oct 17
9	Paramagnetism and Diamagnetism	19	Oct 22
	Magnetic Order: Ferromagnets, Antiferromagnets, Ferrimagnets	20 – 21	Oct 24
10	Mean Field Theory of Magnetism; Hubbard Model (maybe)	22 – 23	Oct 29
	Exam	Exam	Oct 31
11	Defects in Solids		Nov 5
	2D Solids		Nov 7
12	Quantum Wells and Nanoparticles		Nov 12
	Superconductivity: Phenomena		Nov 14
13	Superconductivity: Introduction to Theory		Nov 19
	Ferroelectrics		Nov 21
14	Project Presentations		Dec 3
	Project Presentations		Dec 5

Textbook: *The Oxford Solid State Basics*, Steven H. Simon (Oxford University Press, 2013), (available electronically on PITTCat at

http://pittcat.pitt.edu/cgi-bin/Pwebrecon.cgi?BBID=7645048

Other Books (on reserve at Bevier Engineering Library, G-33 Benedum Hall, or available electronically through PITTCat at
http://pittcat.pitt.edu/cgi-bin/Pwebrecon.cgi?DB=local&PAGE=rbSearch

1. *Solid State Physics*, Neil W. Ashcroft and N. David Mermin (Brooks/Cole, 1976) Well-written, contains much detail, used mostly in graduate courses.
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. *Solid State Physics: An Introduction to Principles of Materials Science*, Harald Ibach and Hans Lüth (Fourth Edition, Springer, 2009) A popular German textbook, written at about the same level as Kittel and Ashcroft & Mermin, available electronically on PITTCat at http://pittcat.pitt.edu/cgi-bin/Pwebrecon.cgi?BBID=7835472
4. *Solid State Physics: Essential Concepts*, David W. Snoke (2009) This textbook by a member of the University of Pittsburgh Department of Physics and Astronomy covers both classic and modern topics. Prof. Snoke uses his book for both the undergraduate and graduate solid state physics courses at Pitt. The book is currently out of print, but a new edition, published by Cambridge University Press, is coming out soon.

Term Paper:

In lieu of a final exam, 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 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. A topic can be a phenomenon, theory, technology, etc. Here's an incomplete list of potential topics for your consideration (Many topics on this list come from a list used by Sergey Frolov when he taught this course. Many "topics" on this list are too broad for a project, but an interesting piece can be selected.):

1. Two dimensional materials: Graphene, transition metal dichalcogenides
2. Quantum dots, wires, or wells; nanotubes
3. Disordered materials, such as glass
4. Quasicrystals (including behavior of electrons or phonons)
5. Polaritons, exciton-polariton condensates
6. Physics of Liquid Helium: ^{4}He or ^{3}He, including superfluidity
7. Impurities and defects in semiconductors, including behavior as quantum qubits
8. Scanning Probe Microscopy (many varieties)
9. High Temperature Superconductivity
10. Quantum Hall Effects (integer, fractional, spin, etc.)
11. Topological insulators (3D or 2D)
12. Majorana fermions in solids
13. Functional materials, oxides, ferroelectrics

14. Large bandgap semiconductors
15. Solar cells, LEDs, solid state lasers, etc.
16. Quantum limited amplifiers
17. Single photon sources; single photon detectors
18. Landauer-Buttiker formalism for transport
19. Magnetic resonance imaging
20. Circuit quantum electrodynamics
21. Quantum opto-mechanics; cooling a mesoscopic system towards its ground state
22. Metamaterials
23. Plasmonics
24. Spintronics: Giant Magnetoresistance, Spin-Valves, Spin-FET
25. Weyl and Dirac Semimetals

The term project is meant to simulate the preparation and submission of a manuscript for publication in a journal. A tentative schedule (and allocation of credit) for the term paper follows:

1. Propose topic, title, brief abstract, sources/references: Thursday, October 3 (5%)
2. Submit paper (15%): Thursday, November 21
3. Oral presentations (5 %): Tuesday and Thursday, December 3 and 5
4. Submit revised paper (5%): Thursday, December 5

Grading:

Your grade will be determined by your performance on the problem sets, midterm exam, term project, and class participation (clickers, quizzes, etc.). The weighting will be as follows:

- Homework: 30%
- Midterm Exam: 30%
- Term Project (Paper and Presentation) 30%
- Class Participation: 10%

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.

Copyright Notice:

Course materials may be protected by copyright. United States copyright law, 17 USC section 101, et seq., in addition to University policy and procedures, prohibit unauthorized duplication or retransmission of course materials. See Library of Congress Copyright Office and the University Copyright Policy.

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.

Inclusivity Statement:

Code of Conduct:

Communication is key to a productive learning environment, and we can maintain productive communication by exhibiting respect for one another. The success of the course for yourself and others depends on all of our commitment to behavior that demonstrates respect for differences, understanding towards others and a willingness to listen and learn. For these reasons, it is unacceptable to harass, discriminate against, or abuse anyone because of race, ethnicity, gender, disability, religious affiliation, sexual orientation, or age. If you witness or are subject to such harassment, please report it to the instructor or to the Office of Diversity and Inclusion: https://www.diversity.pitt.edu/ .

Title IX:

Legal text: "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance."

As a professor I am a mandatory reporter, and I am required to report violations of Title IX that I observe or am made aware of to the Title IX office https://www.titleix.pitt.edu/ . Title IX violations include, but are not limited to, sexual harassment, sexual violence and verbal or sexual abuse. Within the classroom, behavior in violation might appear as: suggestive jokes or innuendos, inappropriate touching, and unwanted sexual behavior or advances, but my capacity and obligation to report does not end at the classroom.