Physics 3716
Advanced Solid State Physics
Winter/Spring 2017 (2174)

Instructor: Robert P. Devaty
Office: 211 Allen Hall
Phone: 412-624-9009
E-mail: devaty@pitt.edu

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. If there is interest, we could set up a weekly session to discuss questions on the homework problems, lectures, etc.

The Course:

This course will start out with an introduction to group theory. The emphasis will be on concepts and results required for applications rather than on the mathematics for its own sake. Point groups and space groups will be discussed. Applications will be made to a variety of topics in solid state physics, and these topics themselves will be developed. An incomplete list of possible topics includes:

- Electron energy bands, phonon dispersion relations
- Electronic level structure and vibrations associated with impurities/defects/complexes in solids, such as the NV (nitrogen vacancy) complex in diamond.
- Selection rules and optical properties (might include interband transitions, excitons, optical behavior associated with impurities and defects, etc.)
- Shallow donors in semiconductors
- Effects of perturbations such as applied magnetic field, stress, etc.
- Tensor properties of crystals: dielectric tensor, elastic tensor, etc.
- Construction of various Hamiltonians: Luttinger Hamiltonian for valence band in cubic semiconductors, perturbation Hamiltonians, etc.
- $\vec{k} \cdot \vec{p}$ theory

If time permits, the course may also cover some topics not necessarily strongly connected to group theory, such as an introduction to superconductivity, electron-phonon interaction, magnetic materials, mesoscopic phenomena, etc. These topics would start out at the level of, *e.g.*, Ashcroft and Mermin, and possibly proceed to a more advanced level.

Prerequisites include knowledge of the basics of solid state physics (e.g., Physics 3715) as well general physics knowledge at the graduate core course level (quantum mechanics, electricity and magnetism, thermodynamics and statistical mechanics, mathematical methods).

Text: The quasi-official text book for this course is *Group Theory: Application to the Physics of Condensed Matter* by M.S. Dresselhaus, G. Dresselhaus and A. Jorio. It is available electronically to University of Pittsburgh students through the University Library System (PittCat Classic). Although I have just started reading this book, it has a good introduction to group theory and presents a variety of applications. I may cover many of the applications in this book, but I may choose to do others as well or instead. The introductory chapters on group theory in Dresselhaus et al. closely mirror the treatment in *Group Theory and Quantum Mechanics* by M. Tinkham, which can be purchased (if you wish) at a reasonable price (paperback published by Dover Publications). My opinion is that the treatment of the basics in Tinkham is slightly better. There are many other books on group theory for physicists and chemists. Some of the books oriented more towards chemists are very well written and don't get bogged down in unnecessary advanced mathematics. For topics in "advanced solid state physics" beyond Ashcroft and Mermin, I may refer to *Advanced Solid State Physics* by Philip Phillips, which is also available on-line through PittCat Classic. For semiconductor physics, a good (albeit somewhat advanced) book is *Fundamentals of Semiconductors* (4^{th} Edition) by P.Y. Yu and M. Cardona. A collection of books will also be available on reserve.

Use of group theory involves frequent consultation of tables. Many books on group theory have tables in the appendices. There is a famous book of tables by Koster et al.; see the list below. An on-line set of tables equivalent to those of Koster et al. is available on Prof. David Snoke's website (there is also a pdf version for download):
http://www.phyast.pitt.edu/~snoke/resources/pointgroupshtml4thEd/PointGroupsFrame.html

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

1. *Group Theory: Application to the Physics of Condensed Matter* by M.S. Dresselhaus, G. Dresselhaus and A. Jorio (2008, available electronically on PittCat), the quasi-official textbook for this course.

2. *Group Theory and Quantum Mechanics* by M. Tinkham. This classic book is also available electronically on PittCat. There is also a copy in the small faculty library, 324 Allen Hall.

3. *Applications of Finite Groups*, John S. Lomont (1959). This book is now published by Dover, and so can be purchased at a good price. It includes a discussion of subduced and induced representations, and the Frobenius Reciprocity Theorem.

4. *Induced Representations in Crystals and Molecules: Point, Space, and Nonrigid Molecule Groups*, Simon L. Altmann (1977), another resource on induced representations, the Frobenius Reciprocity Theorem, etc.

5. *Properties of the Thirty-two Point Groups*, George F. Koster, John O. Dimmock, Robert G. Wheeler and Hermann Statz (1963), a famous set of tables.

6. *Space Groups for Solid State Scientists*, by Gerald Burns and Michael Glazer. This book is an introduction to the International Tables for Crystallography. The recent 3^{rd} edition is available electronically on PittCat. An earlier edition may be placed on reserve.

7. *Advanced Solid State Physics* by Philip Phillips (2012), also available electronically through PittCat Classic.

8. *Fundamentals of Semiconductors* (4^{th} Edition) by P.Y. Yu and M. Cardona. The 4^{th} edition is available electronically on PittCat. An older edition may be placed on reserve.

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

10. *Introduction to Solid State Physics*, Charles Kittel (2005, 8^{th} Edition) A classic textbook. It has been updated, most recently in 2005. Some people prefer earlier editions, particularly the fourth.
11. *Principles of the Theory of Solids*, J.M. Ziman (1972, 2^{nd} Edition) Another classic text. The author has a distinct style, which you may find appealing.
12. *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.
13. *Condensed Matter Physics*, Michael P. Marder (2010, 2^{nd} Edition) Treats a wealth of topics, including many of current interest.
14. *Solid State Theory*, Walter A. Harrison (1970) Detailed discussion of band structure calculations, etc. Harrison has written a number of related books.
15. *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.

Term Project:

In lieu of exams, the capstone experience for this course will be a term-long research project culminating in a 15 - 20 minute PowerPoint presentation to the class towards the end of the term. 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 organizing and clearly presenting a talk on a scientific topic. In consultation with the instructor, you will choose a topic in solid state physics or a recent or classic paper from the literature. 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. Your topic need not have anything to do with group theory.

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

1. Propose topic, with abstract: Tuesday, January 31 (5%)
2. Submit outline with references/sources list (15%): Tuesday, February 20
3. Submit draft PowerPoint slides (40%): Thursday, March 30
4. Present revised Power Point slides; present talk to the class (40%): Final week or two of course

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.

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, available at http://www.as.pitt.edu/fac/policies/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. For more information, visit http://www.studentaffairs.pitt.edu/drs .

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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.