Solid State Physics

Physics 5500-001 (3 cr.) Spring 2014

TR 2:30 – 3:45pm Mendel 362

Instructor:

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Office Hours: Tues/Thurs 1-2:30 PM, or by appointment

Background:

This course is intended primarily for juniors and seniors majoring in Physics, covering topics in Solid State Physics, although the course may also be of interest to students in allied fields such as chemistry and engineering. Some of what we cover will be applicable to liquids, surfaces and interfaces as well. As a more general term this field is therefore known as "condensed matter physics," since the materials under study exist in highly condensed form, in which many atoms or molecules are in close enough proximity to one another to interact strongly. Most of the physical entities we deal with on a daily basis are in such a condensed state, so what we learn in this course will have extremely broad relevance not only to forefront research in science and technology but to our everyday lives as well.

Condensed matter physics is presently the largest subfield of physics, which is no surprise when you consider the importance its results have on our everyday lives. From developments in metallurgy and engineering of structures, tools, and devices, to plastics, to energy production and storage, to electronics and the Computer Revolution, condensed matter physics has revolutionized the world, enabling technological developments that would have been unimaginable a few centuries or even a few decades ago. Indeed, historians delineate periods of history by the materials available: the Stone Age, the Bronze Age, the Iron Age, the Industrial Age, and the Information Age.

Content: The lectures will cover a variety of topics, including:

Crystal Structure, Reciprocal Lattice and Diffraction Measurements
Crystal Binding and Lattice Vibrations (Phonons)
The "Free Electron Gas" and Electrons in a Periodic Potential: Band Theory
Metals, Semiconductors and Insulators
Thermal Properties (e.g. heat capacity due to phonons and electrons)
Transport and Electronic Properties
Optical Properties
Magnetic Properties (e.g. paramagnetism, ferromagnetism)

Depending on available time, we may also cover some areas of forefront research at Villanova and elsewhere, including superconductivity, multiferroicity, nanostructured materials, magnetic frustration, surface physics electronic devices.

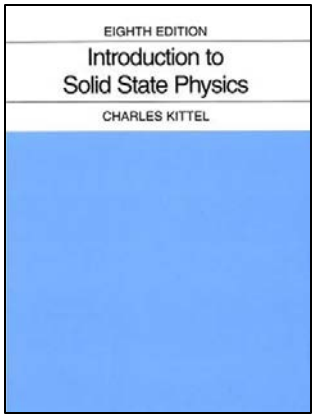
Prerequisites:

The official prerequisites for this course are PHY 2416-7 (Modern Physics and Lab).

Mathematics: I assume that you have a working knowledge of algebra, calculus and ordinary differential equations. I will also assume that you have a passing familiarity with partial differential equations (such as Maxwell's equations and the Schrodinger equation) and with the use of complex variables (e.g. using $Ae^{ix} = A(\cos(x) + i\sin(x))$ to represent waves).

Physics: Most of the physics we need has been covered in PHY 2410-2417. You should be comfortable with the notion of fields (such as E and B fields) and wave properties. You should be comfortable with basic quantum mechanical concepts including wavefunctions, the uncertainty principle, and wave-particle duality. These ideas are extremely important, since many of the ideas in condensed matter physics are predicated on the fact that "particles" have things we usually consider as "waves," such as lattice vibrations, can equivalently be described as discrete "particles" with defined energies and momenta.

Textbook:



The official text for the course will be *Introduction to Solid State Physics*, by Charles Kittel. The most recent edition (which will be available in the Bookstore) is the 8th, but the 7th edition is fine as well. Kittel is a widely-used text, which some consider the "Bible" of undergrad solid state texts. It's an excellent reference book, although it is quite condensed (no pun intended). I do like Kittel's approach, though, which is quite systematic, in terms of introducing new topics in a concrete way, with reference both to the theoretical underpinning and the experimental evidence.

A few "optional" texts which you might consider:

Solid State Physics, by Hook and Hall (2nd edition)

Elementary Solid State Physics, by M. Ali Omar (out of print but used copies might be available)

Solid State Physics, by Ashcroft and Mermin. This is a more advanced book, some would call it "the bible" for graduate solid state physics courses.

Responsibilities:

You are responsible for everything I cover in lecture, unless I say otherwise. There will be lots of things in the text which I will not cover in lecture; you are not responsible for that material but you're welcome to learn it if you are interested. Conversely, there will be some things I cover in lecture that will not be in the text, and when possible will point you to references to help with that.

Exams and Grades: Grading for the course will be:

40% on the two in-class exams
15% on the final project (written report + in-class presentation)
40% on the graded homework assignments
5% for submitting responses to the questions of the week
+ extra credit opportunities

Exams: There will be two in-class exams: a midterm in late February, and a final exam at the time scheduled by the Registrar, together counting for 40% of your final grade.

Final Project: There will be a final report and brief in-class presentation, due toward the end of the semester, counting for 15% of your final grade. This will be on a topic of your choosing, and we will discuss more details as the term progresses.

Homework assignments: There will be 6-8 homework assignments, one every 1.5 - 2 weeks. In the real world, most problems are open-ended, and not conducted under closed-book, timed conditions, so I believe that a large part of your grade should come from something other than in-class exams. Hence I will collect and grade your homework assignments, which count for 40% of your final grade.

Questions of the Week: Approximately once per week I will distribute a question via email. Generally, it will be a conceptual question (and not a mathematical "problem") to get you to think about upcoming material, and to help me get a better idea of what I need to cover in class. Here's how it works: I send out the question, and you respond by the deadline given. If you submit a response, you get full credit, whether the answer is right or wrong. I may reply with comments or suggestions, but there's no penalty for getting the wrong answer. Basically, this is 5% of your grade which you can get "for free," and can make the difference between, say, B+ and A- or A- and A.

Extra Credit Opportunities: Occasionally I will include "challenge" problems for extra credit on homework and exams. There are also a number of opportunities to attend seminars and lectures which are closely related to the course material, chiefly through the Department of Physics Seminar Series, but other venues as well. I will inform you of opportunities to attend such events for credit.

Due Dates and Late Policy:

I spend a lot of time deciding on exam dates and assignment due dates. I confer regularly with the instructors of your other courses, to ensure that my deadlines collide minimally with significant dates in your other courses. As a rule, I always give at least seven full days (and usually more) between when an assignment is set out and when it is due, and I ensure that there are always at least seven days between when a topic is covered in class, and when any graded assignment or examination based on that material is due. So, my due dates are quite generous and offer plenty of opportunities for early completion of assignments.

Further, in the real world externally-imposed deadlines are significant; your boss is not going to be sympathetic to extensions except under exceptional circumstances. We, your Villanova instructors, will have done you a disservice if we sent you out into the workplace without learning the importance of time management and prioritization.

Therefore, I will not entertain any requests for extensions of due dates, or makeups of missed exams, absent exceptional circumstances corroborated by written documentation. If the class feels that a certain due date is unsatisfactory, I will consider granting an extension for the entire class, if informed of the issue well in advance of the due date. I will not, however, permit individual extensions or exceptions as that gives an unfair advantage to those who have received such consideration. If you are not sure if you will be able to submit an assignment on the due date, you have the option of turning it in early. An assignment is not considered "submitted" until it is in my hands; if for whatever reason you leave an assignment for me to pick up it is your responsibility to ensure that I do in fact receive it.

My "late policy" is as follows: Any late submission (as defined above) is subject to a 25% penalty (that is, 25% of the maximum possible score is subtracted from the grade). After one day late, I deduct an additional 25% for each business day after the due date. Once an assignment is more than four business days late, it will not be considered for credit, and a zero will be averaged against your final grade. If there are exceptional circumstances supported by written documentation, I will consider waiving the late penalty, but only for the duration described in the documentation; the 25% daily penalties begin to accrue at the end of that period.

Example: Suppose an assignment is due at a Thursday class. If you turn it in after the class time on Thursday, or on Friday, it's 25% off. If you turn it in over the weekend or on the following Monday, it's 50% off. Tuesday, it's 75% off. After that, it will not be considered for credit. If you cannot make it to that Thursday class, you have the option of handing in the assignment before class.

Academic Integrity and Legalisms:

The Villanova University policy on academic integrity will be in effect throughout the semester. I expect that all work on in-class exams is the result of individual effort without outside assistance. I encourage you to work in groups on the homework assignments, and will make the problem sets challenging in order to stimulate discussion (both amongst yourselves, and with me during class times and office hours), but what you turn in for grading should represent your own work and your own understanding of the problems.

If you are a person with a disability please register with the Learning Support Office at 610-519-5636. They will notify me of your registration and any accommodations necessary.