1 Overview

This course is a general introduction to Solid State Physics. It covers the basic ideas and techniques of the subject, plus a number of examples to illustrate how the basic ideas are applied. It is typically taken by advanced undergraduates in Physics and related fields, and also by graduate students (usually first year Physics or EE majors) that have had little or no previous exposure to the subject.

The emphasis in this course is mainly on basic science. The Physics Department offers an alternative more applied course, intended primarily for students (non-Physics majors) with a poor Physics background. This alternative course is not more advanced (despite its 5-number) but has a very different emphasis and assumes much less previous knowledge of Physics.

1.1 Topics Covered

Here is a guide to the topics that we will cover in the course. Please note that we may not make it all the way to the end.

1. Introduction: how solids are not like classical gases
   - Heat capacity of a crystal: the importance of quantum mechanics and interactions
   - Drude theory (the “Boltzmann gas” model of metals, and where it fails)
   - Towards a proper treatment of metals: the free electron gas

2. Introduction to solids
   - Chemical bonding and tight-binding models: modeling the chemistry of large numbers of atoms
   - Solids in 1 dimension: normal modes, vibrations, and phonons; 1D crystal momentum and Brillouin zone
   - Electrons in 1 dimensional solids (also in a tight-binding approximation)

3. Solids in 3D: the geometry of crystals
   - Lattice basics: unit cell, lattice vectors; some common examples
   - Reciprocal lattice and Brillouin zone in 3D; some examples
   - Electrons in 3-dimensional solids
   - Scattering in crystals: Bragg peaks and structure factors

4. Electrons in solids
   - Electrons in a weak periodic potential: Bloch’s theorem
• Band theory – i.e. metals, insulators, and semiconductors
• Some fun with semiconductors: transport, doping, engineering band gaps, and how to make a transistor

5. Magnetism
• Magnetism of atoms: paramagnetism and diamagnetism
• Spontaneous magnetic ordering (i.e. spontaneous symmetry breaking)
• Domains, hysteresis, and ferromagnets
• Mean-field theory (of the Ising model)
• The microscopics of (antiferro-)magnetism: the Hubbard model

6. Other topics as time permits, such as
• mean-field theory of superconductivity
• Topological defects in magnets
• Landau levels and the integer quantum Hall effect

2 Textbooks and other reading resources
• Steven H Simon: The Oxford Solid State Basics.
  This will be the primary textbook used for the course. It is the only “required” textbook.
• Kittel Introduction to Solid State Physics
  A very standard reference on the subject; it also contains basically all of the material that we cover, albeit in a different order.
• Ashcroft and Mermin: Solid State Physics
  This is a good reference and the “classic” text for a graduate-level course on solid state physics. It covers what we do in class and then some, and goes into more depth on a number of topics. If you want to purchase a text in addition to the required textbook, this would be the best choice.

3 Prerequisites
I will assume some basic knowledge of thermodynamics and statistical mechanics. If you have not taken courses in these areas that doesn’t necessarily mean that you won’t be able to keep up in the course, but you will be responsible for brushing up on these topics on your own. Please don’t hesitate to ask for references if you feel you need extra reading.

More specifically, I will assume that you are familiar with the following:
• Basic quantum mechanics: i.e. the Schrödinger equation (for one particle) and its solutions for a variety of common potentials, such as particle in a box and spherically symmetric potentials.
• Slightly less basic quantum mechanics, such as the variational principle and WKB approximation
• The quantum (and classical!) mechanics of the Harmonic oscillator
• Classical statistical mechanics and thermodynamics, i.e. what is a partition function, a heat capacity, a susceptibility, etc.
• Some very basic quantum statistical mechanics – i.e. what are bosons and fermions (and some familiarity with their distributions \( n_F \) and \( n_B \), which we will use but not derive)

• Some very elementary chemistry: the structure of the atom (shells and orbitals and all of that).

• Fourier transforms.

4 Homework

There will be (approximately) weekly homework assignments, due on Fridays. These will be posted a week before they are due on the course page that you can access through the physics department website.

Please note that late problem sets will not be accepted. Unless you have truly extenuating circumstances (serious illness or injury to yourself or someone in your family, etc.) there will be no exceptions to this policy. However, I will drop your worst problem set when calculating your final grade, so don’t panic if you miss one. (Do panic, however, if you miss several. This is statistically very highly correlated with doing poorly on the exams and getting a bad grade in the course overall).

I will hold office hours on Thursdays, to which you are encouraged to come with questions either about the problem sets or the material discussed in class. You are also encouraged to discuss possible approaches to the problems with your classmates if you find this helpful. Naturally, you must hand in your own version of the solution, and be able to explain it if asked.

5 Evaluation

• Weekly assignments (due Fridays): 20 %.

• Mid-term exam (Weds. March 9) 30 %

• Final exam: 50 %

Letter grades will be based on overall score with 5 % intervals corresponding to +/- increments, that is 15 % increments corresponding to every letter. Thus, you need 45 % to get a D, 55 % to get C-, 70 % to get B-, 85 % to get A-. Grades of 90 % and above translate to an A. (Unfortunately the University does not recognize the A+ grade). Students taking the course on an S/N basis must earn at least a C- to get an S, a D grade is not satisfactory.

6 Academic Integrity

Every student is expected to behave professionally and honestly. (See http://www.finop.umn.edu/groups/ppd/documents/index/AAcontents.cfm for the University conduct code).

No cheating or other unprofessional behavior will be tolerated. Obviously, if you are caught cheating on an exam you will not only fail the course but also be in serious trouble with the university administration. However, don’t forget that that copying homework solutions from another student (or from an on-line source, or from solution sets to similar problems given in previous years, etc. etc.) is also cheating. It will also have a serious impact on your grade and get you into trouble with the university administration. Bear in mind that the repercussions of being caught cheating, even on a problem set, will be far worse than simply not turning in that problem set. So be sensible, and adhere to the university conduct code.
That said, let me emphasize that there is a big difference between copying someone else’s solutions, and discussing your solutions with your peers (or comparing notes to see if you have independently arrived at the same answers). You are more than welcome to discuss the problem sets with other students in the class. The general rule of thumb is that you should be able to explain any solution you turn in without looking at your paper (but with the help of the textbook if you need to refer to some formulae).

7 Legal stuff

For anything not covered above, all relevant University Policies will be followed. A comprehensive index of such policies is at http://www.policy.umn.edu