PHYSICS 342/555 – Structure of Matter, Spring 2017
University of Tennessee, Knoxville

Meeting Place and Time: Nielson Physics, 306. M/W/F 1:25 PM – 2:15 PM.

Instructor: Prof. Steven Johnston
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Office Hours: Wednesday 2:30 PM – 4:30 PM or by appointment.

Course Description: This is an introductory course on the structure of matter. The primary goal of this course familiarizes you with the *quantum* theory of matter at the scale of atoms, and its applications. While we will be studying some aspects of molecular physics, our primary emphasis will be on understanding solids. This course could alternatively be titled *Introduction to Solid State Physics* or *Introduction to Condensed Matter Physics*. I have provided a (tentative) list of topics at the end of this syllabus.

Prerequisites: Solid state physics calls upon elements of quantum mechanics, thermal physics, statistical mechanics, and electricity and magnetism. Throughout this course, I will assume you have had some exposure to the basic concepts of these fields. For example, you should be familiar with notions of wave functions, quantum particles in a box, the Schrödinger equation, the (quantum) simple harmonic oscillator, electromagnetic waves, and some elementary statistical physics.

I do not expect you to be an expert on these topics, and we will review many of them as needed; however, there may be times when you will have to review this material.

Textbook: The primary text for the course is "The Oxford Solid State Basics" by Steve Simon (ISBN-13: 978-0199680771).

The author has provided a list of known errors at:
http://www-thphys.physics.ox.ac.uk/people/SteveSimon/errors.html.

Other References: Previous instructors have used the book "Introduction to Solid State Physics" by Charles Kittel (ISBN-13: 978-0471415268). This text is a widely used introductory textbook, which approaches the subject matter in a different manner than the textbook we will be using. (One of the main differences is that Kittel's book introduces crystal structure at an earlier stage than we will.) If you find the explanations given in Simon's book unsatisfactory, I recommend reading the related material in Kittel's book. If find both books unhelpful, you might consult any of the following:

- "Solid State Physics" by N. W. Ashcroft and N. D. Mermin. (This is an old but good reference book, especially if you planning on pursuing graduate studies in condensed matter physics.)
- "Condensed Matter in a Nutshell" by G. D. Mahan.
- "Elementary Solid State Physics" by M. A. Omar.
- "Solid State Physics: An Introduction" by P. Hofmann.
- "Solid State Physics: Essential Concepts" by D. W. Snoke.
- "Fundamentals of Condensed Matter Physics" By M. L. Cohen and S. G. Louie. (This is a new and somewhat advanced book. It may be best suited for the students enrolled in PHYS-555)

Assessment:
I will be assessing your learning using a mix of homework problems, midterm, and final examinations. The students enrolled in Phys 555 will also be required to write a short paper and give a short presentation on a topic of interest.

Assignments: I will assign problem sets and exercises at regular intervals. These will contain a mix of short explanations, discussion questions, and calculations. Students in Physics 555 may be asked to solve additional parts to some questions or provided extended discussions where appropriate.

Midterm exam: About half way through the term we will have an in-class midterm exam, which will occur during one of our regular class meetings. (The tentative date will be Wednesday, March 8th, 2017. This date is subject to change and will be confirmed closer to the event.)

Final Exam: We will have an in-class final exam at the end of the semester, which occur during the allotted exam time. *The final exam will be cumulative*.

Both the midterm and final exam will be open book exams; you will be allowed to bring the textbook, a calculator, your writing implements, and a single-page single-sided "cheat sheet." No other materials will be permitted.

Project for the Students in PHYS-555:
The students enrolled in the graduate version of this course are required to write a short ~6-8 page paper on a topic related to the course that interests them. They will also give a brief twenty-minute presentation at the end of the semester on the same subject. To discourage procrastination, you will be required to meet several milestones related to this project. The details of this project will be specified in a separate handout, along with a list of potential topics.

Grading (PHYS 342):
For the students enrolled in PHYS-342, your grade will be determined using one of the following distributions.

1. 50% / 20% / 30% for the assignments, midterm, and final.
2. 50% / 10% / 40% for the assignments, midterm, and final.

Grading (PHYS 555):
For the students enrolled in PHYS-555, your grade will be determined using one of the following distributions.

1. 30% / 20% / 20% / 30% for the assignments, project, midterm, and final.
2. 30% / 20% / 10% / 40% for the assignments, project, midterm, and final.

In both cases, I will use the distribution that maximizes your grade. I will convert your numerical grade to a letter grade using the University of Tennessee's standard scale.

Group work policy: I encourage students to work together and discuss the homework with each other. Such discussions are one of the most effective ways of assimilating the material. The work you turn in must be written up by you and not be a copy of your peers or some other source such as solutions found on the Internet. Any homework assignment that is a direct copy of another person's work without attribution will count as a case of plagiarism and dealt with accordingly. Do not take advantage of the work of other people, and do not let anybody benefit from yours.

Late policy: All homework will be due at the beginning of class on the day it is due. No extensions will be given on material without extenuating circumstances (e.g. a note from a doctor etc.) or prior arrangements with me. I almost always grant extensions if you contact me early enough and with good reason. Without an extension, I will reduce the grade on any overdue material by 25% each day that it is late.

Questions and Appeals: I encourage you to ask questions during the lecture or/and talk to me during my office hours (or by appointment – just ask after class) about the subject. You can discuss with me the grading of a given assignment, be it homework, the project, the midterm, or the final exam. Appeals will be entertained if they are raised no later than one week after the day on which the material was made available for return to the class. After this "appeal period," grades will be considered final and will not be altered.

Cell Phones: I do not allow cell phones in the classroom. Your purpose for attending lectures is to learn the course material and take part in the discussion. You cannot do that if you are checking social media during lectures. If you are found using your cell phone during class, you will receive a warning and be asked to put it away. If it happens again after that warning you will be asked to leave the class for the day.

For Students with Disabilities: If you need course adaptations or accommodations because of a documented disability, please contact the Office of Disability Services at 2227 Dunford Hall (phone 865-974-6087; e-mail ods@utk.edu). Doing so will ensure that you are properly registered for services. If you are not registered for such services, I cannot make special accommodations for you.

Academic Honesty: Students are expected to perform all work in conformance with the University policies regarding Academic Honesty. I will peruse cases of academic dishonesty.

List of Topics: I believe that it is better for you to gain a deeper understanding of the core topics, well rather than a superficial understanding of many topics. Therefore, this list of subjects is tentative and is subject to revision. Some items may be assigned to you as supplementary reading assignments.

Part 0: Introductory Remarks

Course Overview	Jan. 12

Part 1: Physics without considering the microscopic structure of matter

Specific heat of solids: Models of Boltzmann, Einstein, and Debye	Jan. 13 –
Conduction in metals: “Drude Theory."	Jan. 31
Sommerfeld Theory of metal (or the degenerate electron gas): Fermi sea, Fermi surfaces, electronic heat capacity.	
Failures of these models.	

Part 2: The structure of materials

The periodic table and its structure.	Feb. 1 –
Chemical bonding: Ionic, covalent, van der Waals, metallic, and hydrogen bonds.	Feb. 3
Types of Matter: metals, semiconductors, insulators, *etc.*.	

Part 3: Re-introducing crystal structure (toy models in 1D)

Atomic vibrations in a 1D monatomic chain: phonons, reciprocal lattice, crystal	Feb. 6 –

momentum. Feb. 13
Atomic vibrations in a 1D diatomic chain: lattice with a basis, acoustic and optical phonons.
Electrons in a 1D monatomic chain: tight binding models and their solution, multiple bands, and electron filling.

Part 4: Geometry and structure of solids

Crystal structure: The bravis lattice, unit cells, atomic basis. Types of crystals. Feb. 15 –
The reciprocal lattice: reciprocal lattice in 1D, 2D, 3D, Miller indices, The reciprocal lattice as a Fourier transform. Feb. 27
X-ray & Neutron Scattering: Scattering amplitudes, Fermi's golden rule approach, Bragg and Laue conditions.

Part 5: Electrons in Solids

Nearly free electron model: degenerate perturbation theory, Bloch's theorem. March 1 –
Bands in two and three dimensions: revisiting the tight-binding models. March. 31
Classification of solids: Metals vs. insulators vs. semiconductors.
Optical properties of solids
Semiconductors: electrons and holes.

Part 6: Further topics and applications

Semiconductor devices: Doping and chemical processes, band structure engineering, p-n junction, and introduction to transistors. April 1 – April. 21
Magnetism: Types of magnetism, Curie and Langevin paramagnetism, Larmor diamagnetism.
Spontaneous magnetic order: ferro-, antiferro-, and ferrimagnetism.