University of Alberta

PHYSICS 541: Condensed Matter Physics I
Fall Term 2015

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Class Web Page: Please search for PHYS 541 in eClass (https://eclass.srv.ualberta.ca/portal/). General announcements about the class, as well as homework assignments/solutions and reading material will be posted on eClass. You are encouraged to visit the site regularly.

Office Hours: Email me to make an appointment. I have also set up a discussion forum on eClass in which I encourage you to participate by posting your own questions as well as answering your classmates' questions.

Lecture Room & Time: CCIS L1-029, Tue/Thu 1:00 pm – 2:20 pm

Course Description: Crystal structure and symmetries; electrons and band structure; semiconductors and heterostructures; lattice vibrations and thermal properties.

Course Prerequisites: I will assume a basic knowledge of classical and quantum mechanics, electromagnetism, and thermodynamics/statistical mechanics. It is important to prepare yourself for this course through a review of the prerequisite material. Students who do not have the required prerequisites at the time of taking this course should not expect supplementary professorial tutoring from the instructor.

Course Objectives:

1. To introduce students to the basic theoretical concepts and experimental probes used in the study of crystalline solids;
2. To have students develop the ability to predict macroscopic properties of crystalline solids from a knowledge of their microscopic constituents and the physical laws that govern them;
3. To have students appreciate the principle of emergence in many-particle systems – that the macroscopic behavior of solids is richer and more complex than one could expect from a naive extrapolation of the microscopic properties of a few elementary particles.

Expected Learning Outcomes:

By the end of this course, students will be able to

1. Distinguish crystal structures, appreciate their role in the cohesion of solids, and compare experimental means of characterizing them;
2. Compute phonon dispersion relations for various crystal structures, use them to predict the effect of phonons on the thermal properties of solids, and compare experimental means of measuring such dispersion relations;
3. Predict the electronic properties of simple metals (i.e., metals with a nearly spherical Fermi surface) by applying the theory of the free electron gas;
4. Compute electron dispersion relations for various crystal structures, use them to predict the electronic properties of metals with generic Fermi surfaces as well as insulators, and compare experimental means of measuring such dispersion relations;
5. Predict the effect of scattering processes (impurity scattering, electron-electron scattering, electron-phonon scattering) on the thermodynamic and transport properties of solids;
6. Predict the electronic properties of bulk semiconductors and simple semiconductor heterostructures.

Course Topics:

These topics are subject to change depending on time availability.

Introduction

Structural properties

- Crystal lattices, point groups and space groups
- Determination of crystal structures: X-ray diffraction, reciprocal lattice
- Interatomic forces, cohesion of solids
- Lattice vibrations, phonons, thermal properties
- Measuring phonon dispersion relations

Electronic properties

- Free Fermi gas model
- Electrons in a periodic potential: Bloch's theorem
- Nearly free electron model, tight-binding model
- Fermi surfaces, band structures, metals and insulators
- Measuring electron dispersion relations

Scattering and transport

- Drude model of electronic conduction and relaxation-time approximation
- Boltzmann equation

- Scattering processes: impurity scattering, electron-phonon scattering, electron-electron scattering

Semiconductors

- Bulk semiconductors
- Heterostructures and confinement: quantum wells, quantum wires, quantum dots
- 2D electron gas, Landau levels, integer quantum Hall effect

Required Textbook: *Solid State Physics*, N. W. Ashcroft and N. D. Mermin

Course material will be taught on the whiteboard in class, drawing mostly from this textbook but also from other sources such as the ones listed below.

Recommended or Optional Learning Resources:

The Oxford Solid State Basics, S. H. Simon
Condensed Matter Physics, M. P. Marder
Introduction to Solid State Physics, C. Kittel
Principles of Condensed Matter Physics, P. M. Chaikin and T. C. Lubensky
Fundamentals of the Theory of Metals, A. A. Abrikosov
A Quantum Approach to Condensed Matter Physics, P. L. Taylor and O. Heinonen
Semiconductor Physics and Applications, M. Balkanski and R. F. Wallis
The Physics of Low-Dimensional Semiconductors, J. H. Davies

Representative Evaluative Material: Example questions representative of the take home final exam will be made available on eClass towards the end of the term.

Grade Evaluation:

EXAMS	**WEIGHTING**	**DATE**
Homework #1	*7%*	*Sep. 15 @ 5:00 pm*
Homework #2	*12%*	*Sep. 29 @ 5:00 pm*
Homework #3	*12%*	*Oct. 13 @ 5:00 pm*
Homework #4	*12%*	*Oct. 27 @ 5:00 pm*
Homework #5	*12%*	*Nov. 17 @ 5:00 pm*
Homework #6	*12%*	*Dec. 1 @ 5:00 pm*
Final Take Home Exam	*33%*	*TBA on eClass*

Students are encouraged to discuss homework assignments (but not the final take home exam) with one another, but are expected to hand in their own work.

A raw total score (out of 100) will be obtained by grading the homework assignments and final exam. The class list will be sorted in descending order of raw total score. Final letter grades (A+,A,A-,B+,B,B-,C+,C,C-,D+,D,F) will then be assigned in a manner that is consistent with an acceptable Grade Point Value average for the class (the equivalence between letter grades and Grade Point Values is described in Section 23.4 of the University calendar). The minimum passing grade for graduate students is C+.

Grades are unofficial until approved by the Department and/or Faculty offering the course.

Missed Term Exams and Assignments:
A student who cannot complete a term assignment due to incapacitating illness, severe domestic affliction or other compelling reasons can apply for *deferral of the weight of the missed term work to the final exam by contacting me.* Deferral of term work is a privilege and not a right; there is no guarantee that a deferral will be granted. Misrepresentation of Facts to gain a deferral is a serious breach of the *Code of Student Behaviour*.

Deferred Final Examination:
A student who cannot write the final examination due to incapacitating illness, severe domestic affliction or other compelling reasons can apply for a deferred final examination. Such an application must be made to the student's Faculty office within 48 hours of the missed examination and must be supported by a Statutory Declaration or other appropriate documentation (Calendar section 23.5.6). Deferred examinations are a privilege and not a right; there is no guarantee that a deferred examination will be granted. Misrepresentation of Facts to gain a deferred examination is a serious breach of the *Code of Student Behaviour*.

Student Responsibilities:
ACADEMIC INTEGRITY: "The University of Alberta is committed to the highest standards of academic integrity and honesty. Students are expected to be familiar with these standards regarding academic honesty and to uphold the policies of the University in this respect. Students are particularly urged to familiarize themselves with the provisions of the Code of Student Behaviour (online at http://www.governance.ualberta.ca/en/CodesofConductandResidenceCommunityStandards/CodeofStudentBehaviour.aspx) and avoid any behaviour which could potentially result in suspicions of cheating, plagiarism, misrepresentation of facts and/or participation in an offence. Academic dishonesty is a serious offence and can result in suspension or expulsion from the University."

All forms of dishonesty are unacceptable at the University. Any offence will be reported to the Senior Associate Dean of Science who will determine the disciplinary action to be taken. Cheating, plagiarism and misrepresentation of facts are serious offences. Anyone who engages in these practices will receive at minimum a grade of zero for the exam or paper in question and no opportunity will be given to replace the grade or redistribute the weights. As well, in the Faculty of Science the sanction for **cheating** on any examination will include **a disciplinary failing grade** (no exceptions) and senior students should expect a period of suspension or expulsion from the University of Alberta.

STUDENTS WITH DISABILITIES: Students who require accommodation in this course due to a disability are advised to discuss their needs with Specialized Support & Disability Services (2-800 Students' Union Building).

ACADEMIC SUPPORT CENTRE: Students who require additional help in developing strategies for better time management, study skills or examination skills should contact the Student Success Centre (2-300 Students' Union Building).

Policy about course outlines can be found in section 23.4(2) of the University Calendar.

Disclaimer: Any typographical errors in this Course Outline are subject to change and will be announced in class. The date of the final examination is set by the Registrar and takes precedence over the final examination date reported in this syllabus.

Note: Audio or video recording of lectures, labs, seminars or any other teaching environment by students is allowed only with the prior written consent of the instructor or as a part of an approved accommodation plan. Recorded material is to be used solely for personal study, and is not to be used or distributed for any other purpose without prior written consent from the instructor.