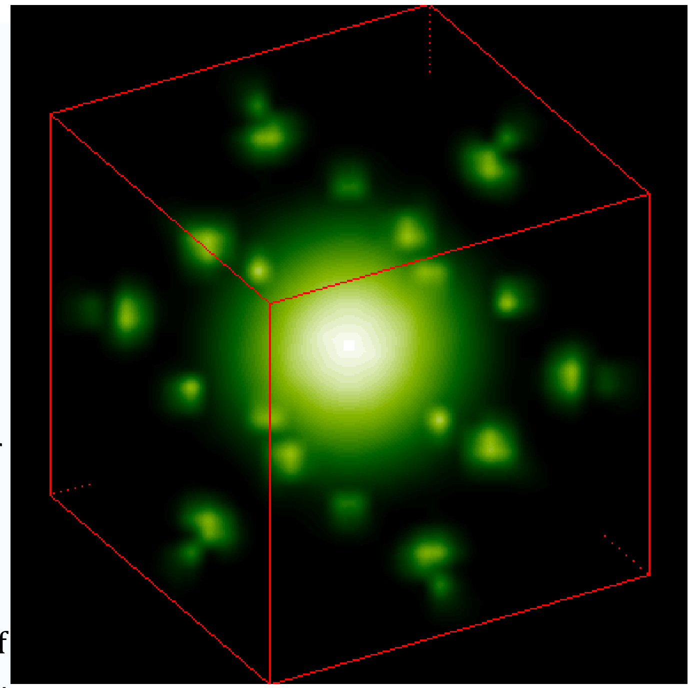
Phys 440 Solid State Physics
Fall 2011
Time: MWF 12:30-1:20
Place: WAT 417A
Instructor: Prof. Klaus Sattler (956-8941), email: sattler@hawaii.edu
Office Hours: W 12:00-1:00 pm
Text: Charles Kittel, Introduction to Solid State Physics, 8th edition (Wiley)
Pre-requisites: Phys 274 and Phys 350(or consent).



Solid-state physics is the largest branch in physics. It is the study of rigid matter, or solids, through methods such as quantum mechanics, crystallography, electromagnetism and metallurgy. Solid-state physics considers how the large-scale properties of solid materials result from their atomic-scale properties. Solid-state physics thus forms the theoretical basis of materials science, as well as having direct applications. This field is responsible for much of the golden age of technology, from transistors and integrated circuits to solid state lasers and superconductors.

Goals: To obtain a basic understanding of the key concepts of Solid State Physics, especially the use and basic applications of quantum mechanics in problems of pedagogical and practical importance. The course objectives will be accomplished through lecture and discussion of selected topics in class, and by students working through the assigned parts of text.

Topics: Fundamental physical properties of crystalline solids discussed in terms of the basic principles of classical and quantum physics. Crystal structure, lattice vibrations, specific heat, energy band theory of metals, semiconductors and insulators.

We will begin with the basics: what is a crystal? What determines the structure of a crystal? How are such structures measured experimentally?

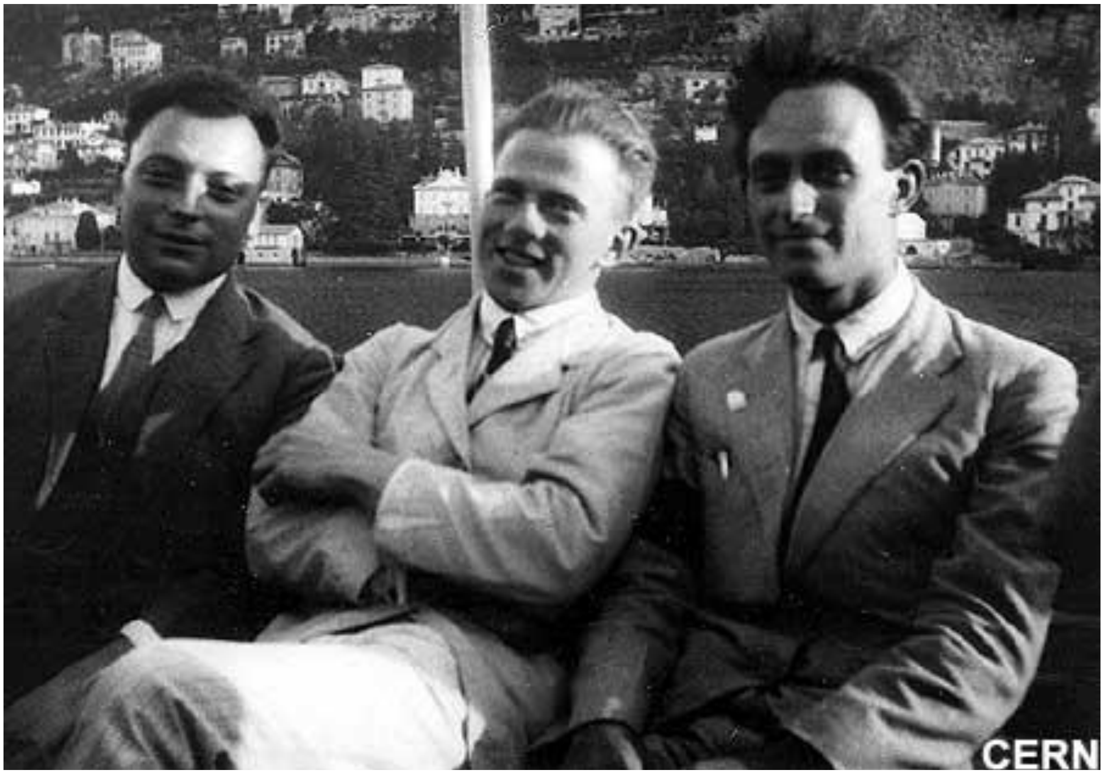
From there we will explore the fascinating subject of heat in solids. We will move to crystal vibrations and thermal properties which will bring us to the concept of Brillouin zones and quantization of elastic waves. Discussion of the phonon heat capacity, anharmonic lattice interactions and thermal conductivity will follow.

Next we will begin the study of the electronic structure of solids. No topic is more central to the properties of solids than their electronic structure. Few measured properties of anything vary over such a large range as the conductivity of solids. From metals to semiconductors to insulators, the differences are enormous. These conductivity differences are determined overwhelmingly by the electronic structure of the material. In this course, we will move from the most simplistic models of electronic behavior to the elegance of density functional theory. We will conclude this section with learning about two of the most interesting electronic properties, superconductivity and magnetism.

One of the fascinating aspects of an introduction to solid state physics is that this is the first time that most students encounter the extreme need for approximate models at the frontiers of physics. The properties of solids, usually consisting of 10^{23} or more electrons, simply can not be determined analytically or even computationally without resorting to theoretical approximations. The many-body Schrödinger equation is just too hard. In this course we will study how approximations can yield results that are accurate and useful.

Course Outline:
Chapter 1: Crystal Structure
Chapter 2: Wave Diffraction and the Reciprocal Lattice
Chapter 3: Crystal Binding
Chapter 4: Phonons I. Crystal Vibrations
Chapter 5: Phonons II. Thermal Properties
Chapter 6: Free Electron Fermi Gas
Chapter 7: Energy Bands
Chapter 8: Semiconductor Crystals
Chapter 9: Fermi Surfaces and Metals
Chapter 10: Superconductivity
Chapter 11: Diamagnetism and Paramagnetism
Chapter 12: Ferromagnetism and Antiferromagnetism

Exams: We will have two in-class midterm exams and the final examination.



Wolfgang Pauli, Werner Heisenberg and Enrico Fermi, 1927, Lake Como

Grading
Grades are based on homework, two midterm and the final exam.
Grade percentages: Homework (30%) Midterm 1 (20%), Midterm 2 (20%), Final exam (30%)
Course grade will be based on grade scale:
A (85 – 100), B (70 – 84), C (50 – 69), D (35 – 49), F(< 35)

SYLLABUS: The syllabus describes the intended progression of the course. The syllabus and homework assignments will be revised as needed. Changes to the syllabus and the homework assignments will be announced in class.

Student Learning Outcomes (SLOs):

General student learning outcomes will be:

(1) explains and interprets physical situations as stated in a word problem
(2) identify the physical laws appropriate to the physical situation at hand
(3) predict the behavior of representative physical systems using mathematics/physical laws as a tool.
(4) interpret the outcome of a physical system .
(5) represent physical systems in multiple representations: i.e., mathematically, pictorially, graphically, etc.

Course Specific Learning Outcomes:

Students should be able to:

- Describe the elementary models for bonding of atoms and molecules and the consequential classifications used in solid state physics; relate the general properties (electrical, thermal and optical) for each class, including details of the expected crystal structures, to the mechanical properties.
- Describe, and perform simple calculations involving, the hexagonal close-packed structure and various cubic structures, which are commonly found in nature.
- Explain how the problem of elastic scattering by a crystal is treated using the concept of the reciprocal lattice and how calculations separate factors which depend on the lattice and on the basis, *i.e.* yield the Laue equations and a structure factor; solve problems relating to representative solid state materials.
- Give a detailed description of the features of the vibrations of monatomic and of diatomic linear chains and explain the significance of dispersion curves in three dimensions.
- Discuss in an informed manner the scattering of phonons, and in particular the occurrence of Umklapp scattering of phonons near the Brillouin zone edge.
- Describe the free electron model and apply it in calculations involving: the dispersion relation, the effective mass, the density of states, the Fermi distribution.
- Use the nearly free electron model to account for the occurrence of energy gaps at the Brillouin zone edges, and the consequent behaviour of the group velocity and effective mass of the electrons.
- explain qualitatively band theory;
- compare the strengths and weakness of free electron and nearly free electron theories;
- state Bloch Theorem;
- draw E-k diagrams;
- describe the concepts of Brillouin zone, Density of States, Fermi energy, effective mass and holes;
- describe the basic optical transitions in semiconductors;
- describe an acceptor and donor;
- distinguish between extrinsic and intrinsic properties of semiconductors;
- define drift, diffusion and thermal conduction and the relations between them for metals, semiconductors and degenerate semiconductors;
- distinguish an insulator, semiconductor and metal
- develop the basic skills of problem solving and critical thinking.