Syllabus PHYS 441

Physics of Condensed Matter I

Typical Textbook

Condensed Matter Physics, Michael P. Marder, Wiley 2000, ISBN 0-471-177779-2

Introduction

This course is the first in a sequence PHYS441-442 dealing with condensed matter physics. Although I would strongly encourage you to take both classes, I intend to make this as much as possible a stand-alone class focused on the basic ideas. Condensed matter refers to both liquids and solids and all kinds of other forms of matter in between those two extremes, generally known as "soft matter". The emphasis of this course will be on crystalline solids. The main reason for focusing on crystals is that the periodicity of a crystal is what allows us to make progress in developing a theory for various phenomena in solids based on first principles. The two most important examples of this are:

- how do we describe the electronic states of electrons in a solid?
- how do we describe the vibrations of atoms around their equilibrium positions?

The answer to the first question is basically the theory of electronic band structure including the reasons why a description in terms of independent, apparently non-interacting electrons works at all? The answer to the second question is the theory of phonons. As you will see , there is a great parallel between these two topics which lies at the core of solid state physics. These two theories form the starting point for understanding a wide range of phenomena:

- how the atoms in a solid bond together to form the crystal, and hence why certain combinations of atoms prefer certain crystal structures, what are their mechanical and some basis statistical properties like the specific heat.
- how electrons move in solids, in other words what are the electronic transport problems, why are some materials metals and other insulators?
- how do solids interact with electromagnetic fields? what are its electrical, optical and magnetic properties?

PHYS441 will focus on band structure theory, the theory of phonons, their immediate implications for bonding and thermodynamic properties and the basics of electronic transport. In PHYS442, we will come back in more detail to transport including scattering phenomena, thermal conductivity, the effects of defects in solids, semiconductors, magnetism and effects beyond the independent electron model, among which the most intriguing one is superconductivity.

Outline of Topics included in PHYS441

- Crystal structures: periodicity, symmetry, experimental determination, non-crystalline condensed matter, introduction to group theory
- Electronic states: Sommerfeld model, thermodynamic properties due to free electrons, band structure basic concepts, Bloch's theorem, density of states, nearly free electron approach and pseudopotentials, tight-binding and linear combination of atomic orbital method, modern band structure methods, justification of independent electron model via density functional theory, application of group theory to energy bands, experimental approaches to measure band structure
- Vibrations in solids: classical treatment, normal modes, quantum treatment, phonons, anharmonic effects, thermodynamic properties related to phonons, continuum approximation and its relation to elasticity
- Motion of electrons: semiclassical model, band velocity, effective mass, motion in magnetic field, cyclotron resonance