EC 577 / MS 577: Electrical Optical and Magnetic Properties of Materials
Professor Theodore. D. Moustakas
Fall Semester 2012

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Office hours: Tuesday 2-5 PM

Lectures: Classroom: Photonics Center (Room 901)
Time: Monday and Wednesday 2-4 PM

Course Prerequisites: Modern Physics or EC471 or EC 574, or equivalent

Required / Recommended texts:


General Overview of the Course and Course Objectives

Purpose of the Course
The purpose of the course is to study the behavior of electrons and phonons in solids and their effects in determining the electronic, optical, magnetic and thermal properties of materials. The course emphasizes the fundamental principles of solid state physics and specific applications.

Benefits to the students
The students will acquire the fundamental knowledge required for the study of more advanced topics in the area of electronic, optical and magnetic properties of solids and their applications to electronic, magnetic, photonic and electromechanical devices.

Grading Policy
Homework 30% of the grade
Mid Term Exam 35% of the grade
Final Exam 35% of the grade
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Class Syllabus

1. **Crystal Structure** (2 lectures)
   - Crystal Lattices
   - Bravais Lattices and Crystal Systems
   - Index Systems for Crystal Directions and Planes (Miller indices)
   - Spacing Between Planes of the Same Miller indices
   - Examples of simple crystal structures
   - Structure of Amorphous Solids and Liquids

2. **Crystal Bonding** (1 lecture)
   - Cohesive energy of Elements
   - Interatomic Forces in Crystals
   - Ionic Crystals
   - Covalent Crystals
   - Metallic Crystals
   - Crystal bonded with Hydrogenic or Var Der Waals Forces

3. **X-Ray, Neutron and Electron Diffraction in Crystals** (2 lectures)
   - Types of Radiation for Crystal Diffraction (X-Rays, electrons, neutrons)
   - Scattering of X-Rays by an Atom
   - Scattering of X-Rays by a Crystal
   - The Reciprocal Lattice and its Properties (Brillouin zones)
   - Calculation of the Crystal Scattering Factor
   - Experimental X-ray Diffraction Methods

4. **Lattice Vibrations: Thermal, Acoustic and Optical Properties** (4 lectures)
   - Elastic Waves
   - Density of Stantes of a Continuous Medium
   - Specific Heat of Solids (Einstein and Debye Models)
   - Phonons
   - Lattice Waves
   - Thermal Conductivity
   - Inelastic Scattering of X-Rays and Neutrons by Phonons
   - Light scattering (Brillouin and Raman) by phonons
   - Microwave Ultrasonic Devices (Phonon amplifier, Surface acoustic wave etc)
   - Lattice Optical Properties in the Infrared (optical phonons, dielectric function, polariton)
5. **The Free Electron Theory of Metals** (4 lectures)

A. The Drude Model
   - Assumptions of the Drude Model
   - DC Electrical Conductivity
   - Temperature Dependence of Electrical Conductivity
   - Heat Capacity of Conduction Electrons
   - Thermal Conductivity
   - Wiedeman-Franz Law
   - AC Electrical Conductivity
   - Optical Properties of Metals
   - Magnetic field effects (Cyclotron Resonance/ Hall Effect)
   - Failures of the Drude Model

B. The Sommerfeld Model
   - Assumptions of the Sommerfeld model
   - Quantum Mechanical Treatment of the Free Electron
   - Fermi-Dirac Distribution
   - Fermi Surfaces
   - Density of States
   - Heat Capacity of Conduction Electrons
   - Electrical Conductivity in the Sommerfeld Model
   - Thermal Conductivity in the Sommerfeld Model
   - Thermionic Emission
   - Failures of the Sommerfeld Model

6. **Band Theory of Solids** (4 lectures)
   - Energy Bands- Bloch Theorem
   - Brillouin Zones
   - Energy Bands in the Near Free Electron Model
   - The Energy Gap and Bragg Reflection
   - Metals, Insulators and Semiconductors
   - Density of States
   - Examples of Fermi Surfaces
   - Velocity of the Bloch Electrons
   - Effective Mass
   - Physical Origin of the Effective Mass
   - Experimental Methods of Determining the Band Structure
   - Limits of the Band Theory- Metal-Insulating Transition

7. **Theory of Semiconductors** (2 lectures)
   - Band structure of Semiconductors
   - Types of Semiconductors
   - Semiconductor Statistics
   - Mobility / Conductivity
   - Semiconductors under high electric fields
- Optical Properties of Semiconductors
- Photoconductivity / Photoluminescence
- Diffusion of carriers in Semiconductors

8. **Dielectrics and Optical Properties of Solids** (3 lectures)
   - Electric Dipole
   - The Dielectric Constant and Polarizability
   - Sources of Polarizability
   - Dipolar Polarizability
   - Ionic Polarizability
   - Electronic Polarizability
   - Piezoelectricity
   - Ferroelectricity

9. **Magnetic Properties of Solids** (4 lectures)
   - Magnetic Dipoles of Atoms
   - Dynamics of a Classical Dipole in a Magnetic Field
   - Zeeman Effect
   - Magnetic Susceptibility
   - Theory of Diamagnetism
   - Theory of Paramagnetism
   - Magnetism in Metals
   - Theory of Ferromagnetism
   - Antiferromagnetism
   - Paramagnetic Resonance
   - Nuclear Magnetic Resonance
   - Ferromagnetic Resonance- Spin Waves

10. **Superconductivity** (2 lectures)
    - Conduction in Normal Metals
    - The superconductive state
    - Materials Showing Superconductivity
    - Critical Field and Critical Current Density
    - Magnetic Properties of Superconductors
    - Thermodynamics of Superconducting Transition
    - Electrodynamics of Superconductors (London Theory)
    - BCS Theory
    - Tunneling and Josephson Junction

10. **Topics in Metallurgy and Defects in Solids** (Extra lectures for students interested on the topics)
    - Types of imperfections
    - Vacancies
    - Diffusion
    - Metallic Alloys
- Dislocations
- Ionic Conductivity
- The Photographic Process
- Radiation Damage in Solids

11. **Materials and Solid State Chemistry** (Extra lectures for students interested on the topics)
- Amorphous Semiconductors
- Liquid Crystals
- Polymers
- Nuclear Magnetic Resonance (NMR)
- Electron Spin Resonance (ESR)
- Chemical Applications of the Mossbaur Effect