UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Solid State Physics

2627-1-F1703Q049

Aims

Introduction of fundamental concepts in Solid State Physics. The aim is to provide the conceptual tools and the notions that are particularly useful to the students undertaking a path in Solid State Physics, digital technologies (ICT) and quantum technologies (QT).

Contents

Structural, electronic and vibrational properties of solids, addressed both from a phenomenological and theoretical point of view.

Detailed program

Theory of metals
• Basic Assumptions of the Model
• Fermi-Dirac Distribution
• Density of allowed wave vectors
• Fermi Energy
• Specific Heat of a free electron gas
• Failures of the Free electron model

Crystals
• Bravais lattices
• Primitive and WS cells
• Crystal Structures and Lattices with bases

• The Reciprocal Lattices
• Brillouin Zones
• Lattice Planes
• X-ray Diffraction
• Bragg and Laue formulations
• Experimental methods
• Geometrical structure factor

Electrons in a Periodic Potential
• The pseudopotential approximation
• Bloch theorem
• BvK boundary conditions
• Crystal momentum, band index and Fermi surface
• Density of levels
• Electrons in a Weak Potential
• Energy levels near a single Bragg plane
• Fermi surface and Brillouin zones
• Semiclassical model of Electron Dynamics
• Wave packets of Block Electrons

Electron dynamics
• General Features of Semiclassical Model
• General Theory of Holes
• Dynamics of electrons (1)
• Semiclassical Theory of Conduction in Metals
• Boltzmann Transport (2)
• Scattering Probabilities
• Impurity scattering

Band Structure of Metals
• Measuring the Fermi surface
• The de-Haas van-Alphen effect
• Electrons in magnetic field: Landau levels
• Density of states in 1D, 2D and 3D electron gases
• Band structure of selected metals

Solids
• Classification of solids
• Covalent, molecular and ionic crystals
o The alkali halides
o Covalent crystals
o Metals
• Cohesive energy
• The Lennard-Jones potential
• Ionic crystals: the Madelung constant
• Cohesion in metals

Harmonic Crystal
• Classical harmonic crystal
• The harmonic approximation
• The adiabatic approximation
• Three dimensional monoatomic Bravais lattice
• The dynamical matrix
• One dimensional monoatomic Bravais lattice
• One dimensional Lattice with basis

• Normal modes and phonons
• Measuring phonons
• Canonical Momentum and Translations
• Neutron scattering
• Quantum theory of harmonic crystal
• High temperature specific heat
• Low temperature specific heat

Superconductors
• A new condensed state
• Diamagnetism
• Absence of low energy excitations
• Electron-electron phonon mediated attractive potential
• Cooper pairs
• Thermodynamics (3)
• Two kinds of superconductors
• Electrodynamics (3)
• Correlation and London lengths
• Metal-superconductor surface energy (type I & II)
• Magnetic Vortexes

Quantum nanostructures
• Semiconductor quantum nanostructure definition
• Band Engineering
• Effective mass approximation for the electronic state calculation
• Quantum well states
• Superlattices
• Wigner-Stark Ladder

Prerequisites

Classical mechanics and electromagnetism, basic quantum mechanics

Teaching form

The teaching will be of type "erogativa", carried out in the context of frontal lessons with blackboard and slides: 21 2-hour lessons held in presence mode.

Textbook and teaching resource

- N.W. Ashcroft & N.D. Mermin, “Solid State Physics”
- Harald Ibach & Hans Lüth, "Solid-State Physics: An Introduction to Principles of Materials Science"
- G. Grosso & G. Pastori Parravicini "Solid State Physics"
- P. G. de Gennes, "Superconductivity of Metals and Alloys"
- John H. Davies, "The Physics of Low-Dimensional Semiconductors: An Introduction"
  Copies of the slides used during lectures

Semester

I Semester

Assessment method

The students' knowledge will be assessed through an oral test. The interview will focus on the topics covered in class. The understanding of the topics and the skills acquired will be evaluated.

Office hours

at the end of the lessons or by appointment

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE