UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Structure of Matter

2627-2-E30004Q012

Aims

To apply the basic principles of classical physics and of quantum mechanics to evaluate the electronic structure of atoms, molecules and solids. To apply those principles to describe the atomic motions in molecules and solids, the thermodynamic properties, the response function of those systems to external electric and magnetic fields and to know the spectroscopies used to derive the fundamental properties of atoms, molecules and solids.

Contents

The fundamental properties of atoms, molecules, and solids will be presented, along with their response functions and with the methodologies which allow one to investigate the main properties of these different forms of aggregation of matter.

Detailed program

- Statistical mechanics: Boltzmann, Fermi-Dirac, and Bose-Einstein distributions.
- Hydrogenic atoms: finite mass effects, spin-orbit interactions, and Rydberg atoms. The Alkali atoms.
- The Helium atom and the exchange interaction. The LS scheme. Hyperfine interactions.
- Polarizability and magnetic susceptibility of an ensemble of atoms.
- Electronic states in molecules: MO-LCAO method, hybrid orbitals, the benzene molecule.
- Motions of the nuclei in molecules: rotational and vibrational motions, and indistinguishability effects.
- Crystal structures and reciprocal lattice.
- Electronic states in crystals and fundamental models to describe the electron dispersion curves. Transport properties.
- Bonding mechanisms in crystals.

- Lattice vibrations and models to describe the thermodynamic properties of phonons in crystals.

Prerequisites

It is important to know the fundamental aspects of mechanics, thermodynamics, electromagnetism, and quantum mechanics. It is also useful to know the basics of statistical mechanics.

Teaching form

Lectures will be held in a hybrid format, with classroom lectures and asynchronous video lectures, which will be made available on the e-learning platform. During the lessons, the program topics will be covered and problem-solving will be used to illustrate the application of what was learned during the lectures. Software that fosters greater student interaction and participation will be used during the classroom lessons. Team work will also be offered.

Textbook and teaching resource

In addition to the asynchronous video lectures, video recordings of the lectures in the classroom, presentation slides, solutions to problems solved in class, and other useful teaching materials will be made available on the e-learning platform.
The reference textbook is A. Rigamonti, P. Carretta, *Structure of Matter: an Introductory Course with Problems and Solutions*, Springer, 2015 (third edition). The topics covered during the course are covered in Chapters 1 through 14 of the book. The sections of the book which are useful for preparation purposes will be specified in the e-learning platform.

Semester

Second semester (from the 1st of March 2027)

Assessment method

Assessment is based on group work on one of the topics proposed by the professor and on a final oral exam. For the oral exam, students are advised to focus on aspects common to the discussions of atoms, molecules, and solids. For example, students must be able to explain the effect of static electric fields on the properties of atoms, molecules, and solids, or be able to discuss the effects associated with particle indistinguishability in atoms, molecules, and solids due to exchange, or describe the spectroscopies used to determine the properties of atomic, molecular, and solids. It is also very important to know or to be able to evaluate the orders of magnitude of the various observables.

Office hours

The appointment can be fixed by sending an email to the professor.

Sustainable Development Goals

QUALITY EDUCATION