UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Struttura della Materia - MZ

2122-3-E3001Q057-MZ

Aims

Understanding the properties of atoms, molecules and solids by means of quantum mechanics and statistical mechanics.

Contents

Elements of classical and quantum statistical mechanics.

Atoms: two-electrons atoms, many-electron atoms in the Hartree theory and the periodic table.

Molecules: electronic states and the chemical bonding, molecular rotations and vibrations, specific heat.

Solids: band theory of electrons in crystals; lattice vibrations.

Detailed program

The course consists of four sections after an introductory lecture on many particle systems.

The reference to specific chapters of the textbooks is given in each section.

Quantum Mechanics of Many Particles Systems

(**(CT)**, chapter 14)

Identical particles: Fermions and Bosons, Slater determinant for independent particles, Pauli exclusion principle.

Statistical Physics

(**(KK)** chapters 2, 3, 5, 6, 7)

- Entropy, temperature and probability.
- Canonical ensemble and the Boltzmann distribution.
- Ideal classical gas.
- Chemical potential, gran canonical ensemble and the Gibbs distribution.
- Quantum distributions functions: Fermi-Dirac and Bose-Einstein distributions.
- Degenerate Fermi gas: Fermi energy, specific heat.
- Boson gas at low temperature: Einstein condensation.

Atomic physics

(**(BJ)** chapters 7 and 8)

- Two-electrons atoms: perturbation theory and variational principle for the ground state.
- Exited states of two-electrons atoms: parahelium and orthoelium.
- Many-electron atoms in the Hartree theory.
- Ground state of many-electron atoms and the periodic system of the elements.
- Corrections to the central field approximation: L-S and j-j couplings, Hund's rules.

Molecular Physics

(**(M)** chapter 3, **(BJ)** chapters 10 and 11)

- The Born-Oppheneimer approximation.

- The electronic structure of the H_2^+ molecule

- The electronic structure of the H_2 molecule: the Heitler-London and the molecular orbital schemes.

- Electronic states in homo- and hetero-nuclear diatomic molecules, covalent and ionic bonding.
- Poliatomic molecules: hybrid orbitals and Huckel model.
- Rotations and vibrations of diatomic molecules.

- IR selection rules in the electric dipole approximation.

- The effects of the nuclear spin on the rotation of the homonuclear diatomic molecules.

- Specific heat of a molecular gas. The theorem of equipartition of energy.

Solid State Physics

(**(M)** chapter 5)

- Lattices and crystal structures.

- Reciprocal lattice, Bragg planes.

- Bloch Theorem
- Band theory: empty-lattice approximation and tight-binding.
- Semiclassical dynamics of electrons in crystals.
- Semiconductors: distribution of electrons and holes in intrinsic semiconductors, n and p doping.
- The pn junction.

Prerequisites

Mathematics and physics courses of the first two years. The first part of the course of Quantum Mechanics.

Teaching form

Frontal lessons.

Textbook and teaching resource

- C. Cohen-Tannoudji, B. Diu, F. Laloe, Quantum Mechanics, volume II, J. Wiley & Sons **(CT)**

- C. Kittel e H. Kroemer, *Termodinamica Statistica*, Boringhieri (Torino 1985) or the English version, *Thermal*

Physics (W. Freeman, 1980). **(KK)**

- N. Manini, *Introduction to the Physics of Matter*, (Springer, 2014). **(M)**

- B. H. Bransden & C. J. Joachain, *Physics of Atoms and Molecules,* 2nd edition, (Harlow – Prentice Hall, 2003). **(BJ)**

Semester

First and second semester.

Assessment method

Students are evaluated through a written exam followed by an oral one.

The written exam consists of three numerical exercises on topics of statistical mechanics, atomic and molecular physics and solid state physics.

A mark of 1.0 points will be given for each exercise correctly solved.

To be admitted to the oral exam a minimum mark of 1.0 points is required (1 exercise correctly solved out of three).

The oral exam will be focused on the exercise non correctly solved and on the theory.

The oral exam must be scheduled in the same session of the written exam.

Office hours

After the lecture, or by appointment in the periods with no lessons.