UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

# COURSE SYLLABUS

## Structure of Matter - Turno M-Z

**2324-3-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 of diatomic and polyatomic molecules, molecular rotations and vibrations, molecular spectroscopy.

Solids: band theory of electrons in crystals, electrical conduction in metals and semiconductors. pn junctions.

### Detailed program

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

While handwritten notes by the teacher are freely distributed, here a reference to specific chapters of textbooks is given:

**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, 6-9 or equivalently **(T)** chapters 1, 2.1-2.4, 3.4-3.5.3, 3.6.1-3.6.3 or **(M)** chapter 4)

- Entropy, temperature and probability.
- Canonical ensemble and the Boltzmann distribution.
- Ideal classical gas.
- Chemical potential, gran canonical ensemble.
- Quantum distributions functions: Fermi-Dirac and Bose-Einstein distributions.
- Degenerate Fermi gas: Fermi energy, specific heat.
- Low temperature Bose gas and the Bose-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 H2 molecule: the Heitler-London and the molecular orbital schemes.
- Electronic states in homo- and hetero-nuclear diatomic molecules, covalent and ionic bonding.
- Electronic states in polyatomic molecules: hybridization and the Hueckel model.
- Rotations and vibrations of diatomic molecules.
- Raman and IR spectra of the diatomic molecule. 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 biatomic molecules. The theorem of equipartition of energy.

**Solid State Physics**

(**(M)** chapter 5)

- Lattices and crystal structures.
- Diffraction experiments and the reciprocal lattice.
- The band theory of electrons in crystals: metals and insulators.
- Semiclassical dynamics of electrons in crystals and the electrical conductivity of metals.
- Semiconductors: distribution of electrons and holes in intrinsic semiconductors, n and p doping, acceptor and donor states.
- Semiconductor devices: 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

- F. Montalenti, handwritten notes.
- C. Cohen-Tannoudji, B. Diu, F. Laloe, Quantum Mechanics, volume II, J. Wiley & Sons **(CT)**
- C. Kittel e H. Kroemer, *Thermal Physics* (W. Freeman, 1980) or the Italian edition, *Termodinamica Statistica*, Boringhieri (Torino 1985). **(KK)**
- N. Manini, *Introduction to the Physics of Matter*, (Springer, 2014), available in e-book on the library website. **(M)**
- B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules,* 2nd edition, (Harlow – Prentice Hall, 2003). (BJ)
- D. Tong, Lectures on Statistical Physics, http://www.damtp.cam.ac.uk/user/tong/statphys.htm. **(T)**

## Semester

First and second semester.

## Assessment method

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

The written exam lasting 2 hours consists of three numerical exercises on topics of statistical mechanics, atomic and molecular physics and solid state physics. The use of books and minute is not allowed during the written exam. Only the use of an electronic calculator is permitted, all other electronic devices are forbidden.

To be admitted to the oral examination it is required that one exercise is completely solved, which assigns 18 points. 6 further points for each additional solved exercise are assigned.

The oral exam will be focused on the discussion of the written exam and on the topics of the lessons.

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

No ongoing partial tests are planned

## Office hours

By apointment, after contacting the teacher via email at least two days in advance.

## Sustainable Development Goals

QUALITY EDUCATION