UNICUSANO ROME

Italian code: ING-INF01 **Credits: 9**
Course: Solid State Electronics
Main language of instruction: Italian
Other language of instruction: English

Head instructor

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Objectives

The course begins with an introduction to basic quantum mechanics. Initially, it covers the experiments that led to the crisis of classical physics and the emergence of quantum mechanics, followed by the introduction of the fundamental mathematical formalism needed to adequately develop the theory.

This foundational topic serves as a basis for the subsequent part of the program, which first elaborates on the fundamental concepts of solid-state physics. In this context, it explores the nature of scattering, starting with two-point scattering in both semiclassical (Van Lue and Bragg conditions) and quantum cases (Born approximation), followed by scattering from a lattice. Inelastic scattering is also presented, both in the semiclassical approximation and through quantum theory.

The next step involves introducing the Born-Oppenheimer approximation within the solid-state physics framework, with some fundamental applications to the study of linear chains with one and two atoms per cell and the dynamics of acoustic and optical branches. The course then delves into some fundamental theories of quantum physics as applied to solid-state physics, including the theory of the quantum harmonic oscillator and

Bose-Einstein statistics, with applications to calculating the Einstein and Debye specific heats.

Subsequently, the course focuses on one of its most significant components: the physics of semiconductor materials, introducing core concepts such as valence bonding, energy bands, the energy-momentum relationship, density of states, intrinsic carrier concentration, and the concepts of donors and acceptors.

The theory of semiconductors forms the basis for explaining charge carrier transport, divided into its two fundamental aspects: carrier drift and diffusion, along with all processes associated with these phenomena. The next stage involves introducing the concepts of injection, generation, and recombination of carriers, leading to the formulation of the continuity equation.

After establishing the foundations of general semiconductor theory and charge carrier transport, students are introduced to the paradigmatic device of solid-state electronics: the p-n junction. This device is studied in detail under thermal equilibrium, as well as with real-device effects caused by recombination-generation, high injection, temperature, and charge accumulation. Some limiting cases, such as junction breakdown, tunneling effect, and avalanche multiplication, are also presented.

The final part of the course is dedicated to a detailed study of the theory and characteristics of various unipolar and photonic semiconductor devices, such as metal-semiconductor contacts, the ideal MOS diode and SiO_2-Si interface, MOSFETs, LEDs, and solar cells.

Course structure

- Periodic Lattices
- Elastic Scattering
- Inelastic Scattering

- Theory of Harmonic Lattice Vibrations
- Thermodynamic Properties of Phonons
- Semiconductors
- Energy Bands and Carrier Concentration
- Charge Carrier Transport
- p-n Junction
- Unipolar and Photonic Devices

Competencies

At the end of the course, the student will have demonstrated the ability to:

A [Knowledge and Understanding]
- Understand the terminology used in the field of solid-state electronics.
- Possess knowledge of the operating principles of the main devices based on solid-state electronics.
- Identify specific solutions to a problem in solid-state electronics.
- Comprehend theories related to solid-state physics.

B [Application of Knowledge]
- Make informed choices regarding the most suitable parameters in a solid-state electronics-based device.

C [Ability to Draw Conclusions]
- Solve analytical and numerical problems related to solid-state electronics and semiconductor physics.

D [Communication Skills]
- Develop a scientifically accurate, rigorous, and comprehensible language to clearly and thoroughly present the technical knowledge acquired in the course.

E [Learning Skills]
- Apply the acquired knowledge to solve original problems related to solid-state electronics.

Evaluation system and criteria

The assessment of the achievement of Learning Outcomes is conducted through the evaluation of E-tivities and the final Exam. The final grade is the sum of the scores obtained from the E-tivities and the Exam. The exam is passed with a minimum of 18 points (18/30).

E-tivity Evaluation

E-tivities are not mandatory but contribute to the final exam grade. The E-tivity assesses all the Learning Outcomes listed for the course, with a particular focus on Learning Skills.

Final Exam Evaluation

The exam, which can be taken either on-site (in Rome) or remotely, consists of a written test comprising exercises related to the course content. The time allocated for the exam is 90 minutes, and responses must strictly adhere to the given questions. The final exam is graded up to a maximum of 30 points (30/30, with possible honors). Clarity in presentation, both graphically and methodologically, as well as explanatory comments to justify the steps taken and enhance readability, will be considered valuable elements in the evaluation. During the exam, students are allowed to use the Theory Handouts provided by the instructor and a scientific calculator (including programmable ones). The use of electronic devices such as computers, tablets, cell phones, or any equipment that enables internet connectivity is strictly prohibited.

Bibliography and resources

Teaching Materials Provided by the Instructor

The educational materials available on the platform are organized into various sections, which include lecture notes, exercises, video lessons, and e-tivities that correspond to the module contents outlined in this syllabus.

The lecture notes provide a summary of the topics covered, which are further elaborated upon in the video lessons. For a comprehensive understanding, it is essential to watch the video lessons while taking notes on the provided lecture materials. This approach will help students thoroughly understand the topics discussed and simultaneously apply theoretical knowledge through the exercises, which are crucial for passing the final exam.

Previous exam papers are also available to help students familiarize themselves with the format of the written exam.

Recommended Educational Materials

For professional reference, it is advisable to include the following texts in your personal library:

- M. Testa, *Fondamenti di meccanica quantistica*, Ed. Nuova Cultura.
- Neil W. Ashcroft, N. David Mermin, *Solid State Physics*, HRW International Editions.
- Charles Kittel, *Introduction to Solid State Physics*, John Wiley and Sons, 2005.
- S.M. Sze, *Semiconductor Devices, Physics and Technology*, Wiley, 1985.