**Code:** ING-INF/01 **Credits:** 9
**Matter:** Solid State Electronics
**Main language of instruction:** Italian
**Other language of instruction:** English

**Teaching Staff**

**Head instructor**
**Prof. Daniele Barettin - daniele.barettin@unicusano.it**

**Introduction**

*1. Objective of the course :*

The course starts from the basis of Quantum Mechanics and Solid State Physics and introduces a rigorous theory for the study of semiconductor physics, in particular regarding transport of charge carriers in semiconductors, analyzing different situations normally present in real devices.
The classic p-n junction is analyzed as a paradigmatic device, then some fundamental unipolar and photonic devices are studied. An equivalent importance is given to the theoretical part, which includes a rigorous introduction to all the models with a complete mathematical treatment and a wide range of analyzed examples, and to the applications, consisting of a vast collection of exercises on the studied subjects.
Some E-tivity (Electronic-Activity) are proposed in the form of Case-Studies and Self-Assessment Tests. Both are necessary for a deeper understanding of some topics of the course, and useful for final grade.
The fundamental purpose of the course is to provide the student with a method of analysis to solve paradigmatic problems that can be extended to realistic and complex situations.

**Objectives**

*2. Course Structure:*

TThe first part of the course is an introduction to basic quantum mechanics: first the experiments which opened to the crisis of classical physics and the birth of quantum mechanics are analyzed, and then the basic mathematical formalism to develop the theory is

introduced.
This first topic is the basis of the second part of the program, which develops the fundamental concepts of solid state physics, studying the nature of scattering, first in the simple case with two points, both in the semi-classical case with Van Lue and Bragg conditions, and in the quantum case with Born approximation, and then the scattering from a lattice. Also inelastic scattering is studied, both with semi-classical approximation and according to quantum theory. Next step is the introduction of Born-Oppenheimer approximation, with some fundamental applications to the study of linear chains with one and two atoms per cell and to the Dynamics of Acoustic and Optical Branches. Some fundamental theories of quantum physics applied to solid state are then studied, such as the quantum harmonic oscillator theory and the Bose-Einstein Statistics, with applications to the calculation of Einstein and Debye Specific Heat. Then we have the study of one of the most important parts of the course, namely the Physics of Semiconductors, with some fundamental concepts: the Energy Bands, the density of states, the concentration of intrinsic carriers and the concept of donors and acceptors.
The theory of semiconductors is the basis for explaining the theory of charge carrier transport, divided into its two fundamental aspects: carrier drift and carrier diffusion. Next step is the introduction to the concepts of Injection, Generation and Recombination of carriers, which lead to the definition of the Continuity Equation.
As soon as the bases of the general theory of semiconductors and carriers transport are given, it is explained to students the paradigmatic device of solid-state electronics: the p-n junction, studying in detail the conditions of thermal equilibrium and then introducing situations of real devices due to recombinationgeneration, high injection, temperature and accumulation of charges. Some borderline cases are also presented, such as junction breakage, tunnel effect and chain effect.
The last part of the course is dedicated to the detailed study of theory and characteristics of some unipolar and photonic semiconductor devices, such as metal-semiconductor contacts, ideal MOS diode and SiO_2-Si diode, MOSFET, LEDs and solar cells.

**Competencies:**
*- Knowledge and understanding:*
understanding of the terminology used in solid state electronics; knowledge of the operating principles of the most important devices based on state electronics solid;
identify specific solutions to a solid state electronics problem; understanding of theories of solid state physics.

*- Application of knowledge:*
choosing the most suitable parameters in a solid state electronics device.

*- Ability to draw conclusions:*
solving analytical and numerical problems concerning solid state electronics and semiconductor physics.

*- Communication skills:*
develop a correct, rigorous and understandable scientific language in order to expose the technical knowledge studied during the course.

*- Ability in learning:*
apply the acquired knowledge for resolution of original problems inherent to solid state electronics.

**Syllabus**

*3. Programme of the course:*

**Subject 1.** Elements of elementary quantum mechanics, periodic lattices, elastic scattering.
**Subject 2.** Inelastic scattering, theory of lattice harmonic vibrations, thermodynamic properties of Fonons.
**Subject 3.** Semiconductors. Energy Bands and Carrier Concentration. Charge carriers transportation.
**Subject 4.** p-n junction.
**Subject 5.** Unipolar and photonic devices.

**Evaluation system and criteria**

Verification of the achievements is carried out through evaluation of the E-tivity and of a Profit Exam, which consists of a written test.

## Bibliography and resources

*4. Materials to consult:*

Teaching materials by the teacher.
Material on the course website is divided into different sections including lecture notes, exercises, video-lessons and e-tivity.
The lecture notes are structured in order to provide a summary of the topics covered, which are then developed in video lessons.

*5. Recommended bibliography:*


- M. Testa, Elements of Quantum Mechanics, 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.