



SOLID STATE PHYSICS I	
Enrollment year	2019/2020
Academic year	2020/2021
Regulations	DM270
Academic discipline	FIS/03 (MATERIAL PHYSICS)
Department	DEPARTMENT OF PHYSICS
Course	
Curriculum	Fisica della materia
Year of study	2°
Period	1st semester (05/10/2020 - 20/01/2021)
ECTS	6
Lesson hours	48 lesson hours
Language	Italian
Activity type	ORAL TEST
Teacher	ANDREANI LUCIO (titolare) - 6 ECTS
Prerequisites	<p>The course assumes basic notions of quantum physics as given in Bachelor courses on modern physics, quantum mechanics, structure of matter. It assumes knowledge of classical electromagnetism and optics. Basic notions of statistical mechanics may be useful (thermodynamic functions, classical and quantum statistics, partition function), anyway they are introduced in the course before being used. For the numerical sessions, no prerequisites are assumed, basic notions of Linux ("minimum survival skills") are useful but will be recalled anyway.</p>
Learning outcomes	<p>a) Knowledge and understanding - The course allows the student to learn the concepts and basic phenomena of solid-state physics through phenomenological descriptions, theoretical treatments and examples. The student will know the main phenomena related to electrons in solids, to lattice vibrations and their quantized modes (phonons), to optical properties, to semiconductors, to the measurement of various physical quantities. He/she will be able to understand and analyze the diagrams</p>

that are commonly used to describe the physical properties of solids, such as energy bands, Fermi surfaces, phonon dispersions, optical absorption spectra, band banding in the p-n junction.

b) Applying knowledge and understanding – The student will be able to apply the above concepts to the understanding of solids concerning, e.g, the order-of-magnitude estimation and the calculation of physical quantities such as the specific heat, the electrical conductivity, the energy gap, the vibrational frequencies, the absorption coefficient, the free-carrier density. He/she will be able to determine which physical quantities can be calculated or measured, with adequate precision. Through a numerical tutorial session on the pseudopotential method, he/she will be able to calculate the energy bands of various tetrahedral semiconductors; this way, the student will familiarize with a typical numerical method of solid-state physics, working in a Linux environment. The teacher will provide examples of Python codes related to topics of the course, and if the students are interested, he will be glad to organize further numerical sessions and/or to introduce working tools like the notebooks.

c) Making judgements – The student will be able to orient him/herself within basic solid-state physics, determining which phenomena and materials are more interesting from the fundamental point of view and more important for applications and technology. For example, he/she will be able to distinguish which materials are insulators, semiconductors or metals knowing the crystal structure and/or the energy bands; or to determine which materials have only acoustic phonons, or also optical phonons, starting from the structure of the crystal lattice. Through the last lectures, which focus on impurity states, surface properties, solar cells, the student will appreciate the importance of solid-state physics in the development of technologies for electronics and for photovoltaics.

d) Communication skills – The student will be able to describe various topics in solid-state physics in a physical language that goes beyond mathematical derivations. During the course, a summary session is organized, in order to train the students to describe the topics with words, without equations, focusing on physical properties.

e) Learning skills – The student will be introduced to some of the reference textbooks in the field and will be able to study those textbooks in autonomy, starting from classroom lectures. He/she will also be able to study analogous textbooks.

Course contents

The course deals with fundamental concepts of solid state physics, focusing on electron levels in crystalline solids, lattice vibrations, optical properties, semiconductor physics. The one-electron approximation is assumed, neglecting the effects of correlation (that are instead treated in the course Solid State Physics II). The topics include: free electrons in metals, Drude and Sommerfeld theories; crystal lattices, Bloch theorem, electrons and holes; classification of solids and chemical bond; energy bands, basic methods for calculations and measurements, Fermi surfaces, electrons in a magnetic field; lattice vibrations and phonons;

optical properties in insulators and semiconductors, complex dielectric function, interband transitions, direct and indirect band gap; excitons, impurities, optical properties of phonons; homogeneous and inhomogeneous semiconductors, drift and diffusion, p-n junction, surface structures, photovoltaic cells (monographic topic, following goal no.7 of Agenda 2030 for sustainable development). The presentation of concepts and theoretical methods is complemented by phenomenological examples, by discussions of the main experimental techniques for the measurement of physical quantities and by computational exercise sessions.

All or part of the lectures may be given in English, upon agreement with all the students.

Teaching methods

UNDER NORMAL CONDITIONS: Blackboard lectures and/or with supporting slides, complemented by a few exercises and lab visits. The course includes at least one discussion/summary session and a numerical exercise session in the computer room. A few homeworks are proposed and later discussed in the classroom, in order to train students to calculate common physical quantities in solid-state physics.

IN CONDITIONS OF MIXTED OR FULLY ONLINE TEACHING BECAUSE OF CORONAVIRUS: Lectures will be held online via Zoom platform, using slides and/or notes with graphics tablet. In case of mixed teaching, lectures will be held in the classroom, projected on the screen and transmitted online. Lectures will be recorded and made available on Kiro together with supporting material (slides and/or video-notes). Numerical exercises will be held online, students will be able to participate interactively from their own computer using Linux or installing a Virtual Machine that has been tested in the previous academic year.

Video-recording of the lectures in English are available on the Kiro platform.

The course is English-friendly:

- 1) The teaching material (textbooks, slides.) is in English;
- 2) The exam can be held in English, upon request by the student;
- 3) Part or all of the lectures can be held in English, upon agreement with the students.

Reccomended or required readings

N.W. Ashcroft, N.D. Mermin, Solid State Physics (Holt-Rinehart, 1976).
G. Grosso and G. Pastori Parravicini, Solid State Physics (Academic Press, 2000; 2nd ed., 2014).

P.Y. Yu, M. Cardona, Fundamentals of Semiconductors: Physics and Material Properties, 4rd edition (Springer, 2010).

J. Nelson, The Physics of Solar Cells (Imperial College Press, London, 2003).

Assessment methods

Oral exam on the course topics (via Zoom or Skype if necessary). At the end of the course, a detailed program is given specifying which topics are optional. At the exam IT IS NOT REQUESTED to repeat all mathematical derivations that are presented in the lectures (this would be impossible, or it would require an excessively long preparation time). The students should instead illustrate the main topics of the course focusing on physical properties, on experimental methods to measure

the various quantities, on qualitative trends, on connections among various chapters. The main goal of the exam is to verify that the student has acquired knowledge, understanding, autonomy according to the above-mentioned teaching goals. If a student has actively attended the lectures, the teacher estimates he/she will be able to prepare the exam in an average period of 2/3 weeks. Looking forward to the exam, it is very useful to reorder and tidy-up the notes after each lecture. The exam may be held in English, if so requested.

Further information

Video-recordings of the lectures held in the a.y. 2015/2016 (mostly in English) are available on the Kiro portal.

**Sustainable development
goals - Agenda 2030**

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