UNIVERSITÀ DI PAVIA

Anno Accademico 2018/2019

SOLID STATE PHYSICS II	
Enrollment year	2017/2018
Academic year	2018/2019
Regulations	DM270
Academic discipline	FIS/03 (MATERIAL PHYSICS)
Department	DEPARTMENT OF PHYSICS
Course	
Curriculum	Fisica della materia
Year of study	2°
Period	2nd semester (04/03/2019 - 14/06/2019)
ECTS	6
Lesson hours	48 lesson hours
Language	Italian
Activity type	ORAL TEST
Teacher	ANDREANI LUCIO (titolare) - 4 ECTS Cococcioni Matteo - 2 ECTS
Prerequisites	The course requires basic notions of quantum physics, electromagnetism, optics, typically learned in the first three years of physics. It also required basic notions of the physics of solids, as given in the course Solid State Physics I. However, interested students from other areas (e.g., theoretical physics) may enroll in SPP II and recover only a few needed topics from SSP I.
Learning outcomes	a) Knowledge and understanding – The course will allows students to learn concepts and phenomena in advanced solid-state physics, including the effects of correlation, which go beyond the single-particle approximation. Students will familiarize with the concept of elementary excitations in solids (plasmons, phonons, excitons, polaritons.) and with their phenomenology. Students will be exposed to current research areas (computational solid-state physics based on density-functional theory, surface plasmons, photonic crystals, correlated systems

described by Hubbard and Anderson models, Mott insulators, superconductivity), also in view of choosing their research and thesis topics. Some of the course topics, especially concerning strongly correlated systems, are also of interest for theoretical physics.

b) Applying knowledge and understanding – The student will be able to appreciate the importance of correlation effects, and to decide on the approaches that are more appropriate for an advanced description of the electronic structure, optical and transport properties in solids. He/she will acquire the capability to employ simple models whenever possible (e.g., the Thomas-Fermi model for screening, the Drude model for the electrodynamics of metals, the relaxation-time approximation for transport), knowing their limitations. He/she will be able to describe various kinds of elementary excitations from the points of view of both theory and phenomenology, and to use the second-quantization formalism for fermionic operators.

c) Making judgements – The student will be able to orient him/herself in the field of advanced solid-state physics, evaluating the most interesting phenomena and the theoretical approaches that are more appropriate to describe the physical properties of various types of complex solids. He/she will have an overview of very different research areas (computational physics, plasmonics, photonics, transport, correlated systems, superconductivity), judging on their interest and importance.

d) Communication skills – Students will assimilate the language of advanced solid-state physics, especially regarding the terminology of correlated systems (exchange, correlation, static/dynamic screening.). He/she will be able to describe various topics in physical language, going beyond mathematical derivations or numerical approaches, which are often very complex in this field.

e) Learning skills – Students will be introduced to some textbooks and recent reviews, and will be able to study them in autonomy after attending the lectures. Moreover, through a session dedicated to paper presentations, they will train on reading and summarizing a scientific paper on a topic of active research.

Course contents

The course deals with advanced concepts of solid state physics, focusing on correlation effects, elementary excitations in solids, quantum treatments of correlated systems and of superconductivity. The topics include: (1) Hartree-Fock method, exchange and correlation effects, screening; (2) density-functional theory and modern methods for the calculation of energy bands; (3) electrodynamics in metals, linear-response theory, Lindhard dielectric function, volume and surface plasmons; (4) excitons and polaritons; (5) photonic crystals, photonic and electronic confinement, nanocavities; (6) Boltzmann equation and transport coefficients; (7) Fermi liquids, second quantization, correlations in solids, Mott transition, Hubbard and Anderson models, Kondo effect; (8) topological phases in condensed matter; (9) effective electron-electron interaction and overscreening, Cooper pairing, quantum (BCS) theory of superconductivity. The presentation of concepts and theoretical methods will be complemented by

	phenomenological examples, by discussion of the main experimental techniques for the measurement of physical quantities, by visits to laboratories (plasmonics, photonic crystals, superconductivity). Videos of the lectures are available on the UNIPV Kiro platform. All or part of the lectures may be given in English, upon agreement with the students.
Teaching methods	Blackboard lectures and/or with slides, according to the topic. The course is completed by a few exercises and by visits to research labs (plasmonic, photonic crystals, superconductivity). Video-recording of the lectures in English are available on the Kiro platform.
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, 2nd edition (Academic Press, 2014). C. Kittel, Introduction to Solid State Physics, 8th edition (John Wiley & Sons, 2005). R.M. Martin, Electronic Structure - Basic Theory and Practical Methods (Cambridge University Press, 2004). Lecture notes and slides.
Assessment methods	Oral examination. The student has to prepare the three basic topics (1)-(3) and another three topics chosen among (4)-(9). The examination starts with a topic chosen by the student, which should be presented in some detail. Generally it is not requested to present detailed mathematical derivations as given in the lectures. Students should rather present the topics from a physical point of view, illustrating the main concepts, trends, figures, methods for measuring the physical quantities, connections among different chapters. 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	$lbl_legenda_sviluppo_sostenibile