COURSE DATA

DATA SUBJECT

Code: 34263
Name: Solid-state physics
Cycle: Undergraduate Studies
ECTS Credits: 7.5
Academic year: 2026-27

STUDY (S)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	4	First quarter, Second quarter
1928 - Double Degree Program Physics-Mathematics	Facultat de Ciències Matemàtiques	5	First quarter, Second quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Expansion of Physics	COMPULSORY
1928 - Double Degree Program Physics-Mathematics	Quinto Curso (Obligatorio)	COMPULSORY

COORDINATION

CROS STOTTER ANA

SANCHEZ ROYO JUAN FRANCISCO

SUMMARY

In this subject extensive use is made of the tools developed in the subjects of Mechanics, Electromagnetism, Thermodynamics, Quantum Physics, and Statistical Physics.

Some fundamental aspects of the Solid State have already been introduced in the subject of Quantum Physics: the Bloch theorem, the existence of energy bands (Kronig-Penney model) and the related dispersion relations, the periodic conditions of Born-von Karman, the effective mass or the concept of hole. The Drude model of conduction in a metal is also studied. These concepts are assumed to be known, although some of them are reviewed in the context of the corresponding topic. Many of the concepts developed in Quantum Mechanics are also of importance for Solid State Physics, particularly in the study of semiconductors, and in the understanding of cooperative phenomena.

The development of the subject analyzes the long-range periodicity and the symmetries to which it gives rise. The different crystalline systems are studied and examples of structures of fundamental and

technological interest are considered. The phenomenon of X-ray diffraction in crystals is analyzed, introducing the reciprocal lattice and the Brillouin zones and describing some methods of resolution of crystal structures.

The problem lattice dynamics is addressed, obtaining the dispersion relations and introducing the concept of phonon. Brillouin and Raman scattering are formulated in a simple way for the study of acoustic and optical phonons, respectively. The thermal properties of solids are closely related to phonons. The density of states of phonons is defined, which will serve as the basis for the determination of a series of thermal properties such as heat capacity, thermal expansion or anharmonicity effects.

The electronic structure of solids is essential to understand their electronic and optical behavior. Two models are addressed, the quasi-free approximation, valid for metals, and the strongly bound electron approximation, valid for insulators. The band structure in the first Brillouin zone is analyzed and the concept of critical points is introduced. This knowledge is applied to the analysis of some band structures of materials of interest and their densities of states, relating their characteristics to the optical and electrical properties of the material.
The study of conductors deals with the semi-classical description of electronic transport, discussing why some materials conduct electricity and others do not. The Drude model is reviewed, emphasizing its weaknesses and the need to introduce Fermi statistics to describe the electron gas. Likewise, the contribution of electrons to thermal conduction is studied.

Semiconductors are the basis for much of today's electronic technology. After recalling some concepts that have been introduced in Quantum Physics, such as the concept of hole and effective mass, the concentration of electrons in a semiconductor and the evolution of the Fermi energy as a function of temperature are determined. Doped semiconductors are studied.

The magnetic properties of matter are addressed by describing the quantum theory of diamagnetism and paramagnetism. Ferromagnetism, together with other variants of magnetic order, is a cooperative phenomenon whose description requires the introduction of the so-called exchange interaction. The mean field theory of both ferromagnetism and antiferromagnetism is discussed.
Finally, an overview of the phenomenon of superconductivity is given, starting from some essential experiments and then making a phenomenological description of its properties. The origin of superconductivity is exposed in a simplified way and the different types of superconductors are analyzed.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

The following prior knowledge is recommended:

General Physics, Mechanics and Waves, Quantum Physics, Thermodynamics and Statistical Physics, Optics, Electromagnetism, Mathematical Methods.

COMPETENCES / LEARNING OUTCOMES

1105 - Degree in Physics

Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.

Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.

Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.

Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.

Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.

Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.

Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .

Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.

Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.

Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.

Theoretical understanding of physical phenomena: have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena).

To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.

DESCRIPTION OF CONTENTS

1. Crystal structure

Crystalline and amorphous solids: short and long distance order. crystal lattices. Bravais lattice and atomic-basis of a crystal structure. Symmetries. Significant crystal structures.

2. Diffraction in periodic structures

Reciprocal lattice. First Brillouin zone. Diffraction by a periodic grating: Laue interference condition and Ewald sphere. Bragg's interpretation of the Laue condition. Structure factor. Experimental devices.

3. Lattice dynamics

Adiabatic and harmonic approximations. Linear chain with one and two atoms in the unit cell: acoustic and optical branches. Examples of real dispersion relations. Wavevector of lattice vibrations. Brillouin and Raman effects for the study of acoustic and optical modes.

4. Thermal properties of solids

Phonon dispersion relationships and density of states. Thermal excitation of phonons: thermal energy and heat capacity. Debye approximation for the harmonic solid. Specific heat. Anharmonic effects. Thermal expansion. Thermal conductivity.

5. Electronic structure. Band Theory

Schrödinger's equation of the electron in a periodic potential: Bloch's theorem. Quasi-free electron approximation. Tight-binding approximation. Band dispersion in the first Brillouin zone: metals and semiconductors. Density of states: critical points or Van Hove singularities. Examples of band structures of real solids. Relationship with its electrical and optical properties.

6. Metals

Drude model and associated problems. Free electron gas in a quantum well with infinite potential barriers. Fermi energy, density of states and Fermi surface.
Statistics of Fermi-Dirac. Electronic contribution to specific heat in a metal. Model of Sommerfeld.

7. Semiconductors

Band structure of semiconductors near to the gap: effective masses and concept of hole. Fermi level and its temperature dependence. Electrons and holes concentrations in an intrinsic semiconductor. Impurities: donor and acceptor. Temperature dependence of the Fermi level and carrier concentration of in a doped conductor. Drude model for a semiconductor. Carrier scattering by phonons and impurities.

8. Electronic correlation, magnetism and superconductivity

Electronic correlation. Magnetic moment of an atom. Exchange interaction. Spin Hamiltonian for ferromagnetism. Mean field theory of ferromagnetism and antiferromagnetism. Basic properties of superconductors. Microscopic description. Zero resistance and Meissner effect.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	60,00
Laboratory	15,00
Total hours	**75,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	0,00
Preparation of lessons	92,50
Preparation for assessment activities	20,00
Resolution of case studies	0,00
Total hours	**112,50**

TEACHING METHODOLOGY

Theoretical lectures: The bases of the Solid State are established, introducing the fundamental aspects from which their electrical, optical and magnetic properties are derived.

Practical lectures: Exercises are carried out that complement the theoretical classes. An attempt is made to introduce real physical magnitudes that allow the student to know the order of magnitude of the different physical parameters involved in their properties.

Laboratory sessions: The laboratory work will be carried out in small groups. The students work in group in taking the data and discussingf the results, in a preliminary analysis.

EVALUATION

The evaluation system considers both the assimilation of the aspects explained in the classes of theory and problems as the laboratory work. The written exam (80%) will test the comprehension of the theoretical-practical aspects and the formalism of the subject, both through theoretical and through conceptual and numerical questions. It will also include problems that assess the capacity to apply the concepts studied and the critical capacity regarding the numerical results obtained. The laboratory grade (20%) is based on a continuous evaluation of the questionnaires delivered and the work done in the laboratory.

The weight of the continuous assessment can be increased by an additional 10% by solving the problems and tasks that are indicated. In that case, the weight of the exam grade will be 70%. For the final grade, the itinerary that most favors the student (with or without additional continuous assessment) will be considered.

The subject will be passed with an average grade equal to or greater than 5, which will be obtained by weighting the different contributions (examination, laboratory and, where appropriate, additional continuous evaluation) with the criteria indicated above. To carry out this weighting, the minimum grade for the exam and the laboratory must be 4 points out of 10.

These evaluation criteria are common to the first and second calls.

REFERENCES

- Solid State Physics, G. Burns, Academic Press, 1990.
- Solid State Physics, H. E. Hall, John Wiley & Sons, 1982.
- Quantum Theory of Solids, C. Kittel, Wiley, 1987.
- Solid State Physics, N. W. Ashcroft y N. D. Mermin, Holt-Saunders Int. Edt., 1976.
- Solid-Stated Physics: An introduction to principles of Materials Science, H. Ibach y H. Lüth, Springer, 2003.
- The Oxford Solid State Basics, Steven H. Simon, Oxford University Press (2013).
- Física del estado sólido. Ejercicios resueltos. Jesús Maza, Jesús Mosqueira y José Antonio Veira. Universidad de Santiago de Compostela.