Approval date: 21/06/2024

COURSE GUIDE

# Solid-State Physics (2671141)

| Grado (Bachelor's Degree) | Grado en Física | Branch | Sciences |
|---|---|---|---|
| Module | Estructura de la Materia | Subject | Física del Estado Sólido |

| Year of study | 4º | Semester | 1º | ECTS Credits | 6 | Course type | Compulsory course |
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## PREREQUISITES AND RECOMMENDATIONS

It is recommended to have taken Classical Mechanics, Electromagnetism, Statistical Physics, Physics Quantum Physics

## BRIEF DESCRIPTION OF COURSE CONTENT (According to the programme's verification report)

Crystal structure of solids
Description of radiation-crystal interaction
Phonons
Thermal properties of solids
Electronic states
Band structure. Transport properties
Cooperative phenomena. Superconductivity

## SKILLS

### GENERAL SKILLS

- CG01 - Skills for analysis and synthesis
- CG03 - Oral and written communication
- CG06 - Problem solving skills
- CG08 - Critical thinking
- CG10 - Creativity
- CG13 - Knowlegde of a foreign language

### SUBJECT-SPECIFIC SKILLS

- CE01 - Knowing and understanding the phenomena of the most important physical theories
- CE02 - Estimating the order of magnitud in order to interpret various phenomena

- CE05 - Modelling complex phenomena, translating a physical problem into mathematical language
- CE07 - Transmitting knowledge clearly, both in academic as in non-academic contexts

## LEARNING OUTCOMES

- Knowledge of the structure of solids, with special attention to their translational and point symmetries. Spatial view of periodic structures
- Understanding the basic notions of scattering or dispersion of radiation by an ordered solid. X-ray, electron and neutron techniques.
- Notions of structure determination methods.
- Understanding the phenomenology of lattice vibrations as an essential aspect of the Physics of Solids.
- From Classical Mechanics of oscillations and waves to waves in periodic media.
- An essential step: quantum formulation and the concept of phonon.
- Scattering is not always elastic: Experimental determination of the phonon spectrum.
- Energy of lattice vibrations: heat capacity of solids.
- Electrons as charge transport particles in solids. Classical theory: Drude's model.
- Understanding the importance of the Pauli principle: Sommerfeld model of the free electron gas.
- The notion of the band as an essential tool in the description of electronic structure.
- Applications: knowledge of the basic mechanisms of electrical and thermal conduction,
- Hall effect and thermoelectric phenomena.
- Basic knowledge of magnetism in matter.
- Superconductivity: experimental facts and models

## PLANNED LEARNING ACTIVITIES

### THEORY SYLLABUS

**Chapter 0. Introduction**

1. Purpose and definition of Solid State Physics
2. Brief history of its development
3. Interest and need for its study

**Chapter 1. Crystalline structure of solids**

1. Translational symmetry: lattice and structure
2. Base and cell. Primitive cell
3. Classification of crystal lattices
4. Reciprocal lattice
5. Positions in the crystal. Miller indices
6. Brillouin zones
7. Examples of crystal structures
8. Bragg equation

**Chapter 2. Phonons. Thermal properties of solids**

1. Introduction

2. Vibrations of a linear monoatomic lattice. Dispersion
3. Vibrations of a three-dimensional lattice with monoatomic base. Normal modes
4. Vibrations of diatomic linear lattices: acoustic and optical branches
5. Three-dimensional lattices with polyatomic basis
6. Quantization and phonons
7. Inelastic scattering of neutrons by phonons
8. Inelastic scattering of electromagnetic radiation
9. Specific heat of the lattice: Born and von Karman's model

**Chapter 3. Electronic structure of solids**

1. Experimental characteristics and the free electron model.
2. Energy levels and density of states.
3. Fermi-Dirac distribution. Fermi energy
4. Limitations of the free electron model
5. Independent electrons: Bloch theorem and energy bands
6. Band calculation models
7. Examples of band structure. Conductors, insulators, semiconductors

**Chapter 4. Transport phenomena in solids**

1. Introduction
2. Transport phenomena in the free electron gas. Drude's model
3. Electron dynamics in the lattice: semiclassical model.
4. Effective mass. Holes
5. Semiclassical conduction theory. Relaxation time approximation

**Chapter 5. Magnetism**

1. Introduction: origin of atomic magnetism
2. Diamagnetism
3. Atomic paramagnetism: Curie's law
4. Pauli's paramagnetism
5. Weiss mean field theory
6. Heisenberg's exchange interaction
7. Magnetic order: ferromagnetism, ferrimagnetism and antiferromagnetism
8. Spin waves
9. Hysteresis, domains and Bloch walls

**Chapter 6. Superconductivity**

1. Introduction. The phenomenon of superconductivity
2. Thermodynamic properties. London equations. Penetration length
3. Ginzburg-Landau model
4. Microscopic theory: BCS
5. Tunnel currents and Josephson effects
6. High-temperature superconductivity

## PRACTICAL SYLLABUS

1. X-ray diffraction
2. Electron diffraction
3. Phonons in a crystal lattice. Laboratory demonstration using electrical analogies

4. Superconductivity
5. Electrical and thermal conductivity of metals
6. Effect of temperature on the conductivity of metals
7. Determination of the bandgap of germanium
8. Hall effect in semiconductors
9. Hall effect in metals
10. Photoconductivity
11. Ferromagnetic hysteresis
12. Nuclear magnetic resonance

## RECOMMENDED READING

### ESSENTIAL READING

**Intermediate-level textbooks:**
*N.W. Ashcroft, N.D. Mermin, Solid State Physics, HRW Int. Eds., Philadelphia, 1981
*J.S. Blakemore, Solid State Physics, W.B. Saunders, Philadelphia, 1974
*G. Burns, Solid State Physics, Academic Press, Boston, 1990
*A.J. Dekker, Solid State Physics, Prentice Hall, Englewood Cliffs, 1965.
*R.P. Huebener, Conductors, Semiconductors, Superconductors. An Introduction to Solid State Physics. Springer, Cham, 2016.
*H. Ibach, H. Lüth, Solid-State Physics. An Introduction to Principles of Materials Science, Springer, Dordrecht, 2009
*C. Kittel, P. McEuen, Introduction to solid state physics, John Wiley & Sons, Hoboken, 2005.
*S.H. Simon, The Oxford Solid State Basics, Oxford University Press, Oxford, 2013

### COMPLEMENTARY READING

**Problems**:
*F. Han, Problems in solid state physics with solutions, World Scientific, N. Jersey, 2012.
*L. Mihály, M.C. Martin, Solid state physics: problems and solutions, Wiley, N. York, 1996.

## RECOMMENDED LEARNING RESOURCES/TOOLS

- https://ocw.mit.edu/courses/8-231-physics-of-solids-i-fall-2006/download/
- https://ocw.mit.edu/courses/6-730-physics-for-solid-state-applications-spring-2003/
- http://www.physics.udel.edu/~bnikolic/teaching/phys624/lectures.html
- https://ocw.mit.edu/courses/8-512-theory-of-solids-ii-spring-2009/
- http://www.xtal.iqfr.csic.es/Cristalografia
- https://www.youtube.com/watch?v=fBo9qRtA83k

## TEACHING METHODS

- MD01 - Theoretical classes

## ASSESSMENT METHODS (Instruments, criteria and percentages)

### ORDINARY EXAMINATION DIET

Assessment will be based on exams, in which students will have to demonstrate the competences acquired, laboratory experiments and the delivery and/or presentation of proposed seminars and problems. Participation, initiative, originality and quality of the work carried out by the student, both in the exams and in the daily work will be especially valued. The overall passing of the course will not be achieved without a uniform and balanced knowledge of the whole subject.
Assessment will be based on the marks obtained in the following activities:
1. Theory and problems exam. This exam will be 70% of the final mark. It is a prerequisite for passing the course to achieve a minimum grade of 3.5 points over 10 in this activity.
2. Laboratory experiments: 20% of the final mark.
3. Written test consisting on the resolution of a problem at the end of each of the chapters. Maximum grade for this activity: 10% of the final grade.

### EXTRAORDINARY EXAMINATION DIET

Assessment will be based on the marks obtained in the following activities:
1. Theory and problems exam. This exam will be 80% of the final mark. It is a prerequisite for passing the course to achieve a minimum mark of 3.5 points over 10 in this activity.
2. Laboratory experiments: 20% of the final mark. The student should carry out one experiment of the laboratory, randomly selected. Afterwards, he/she will present an oral report of the practical carried out.

### SINGLE FINAL ASSESSMENT (evaluación única final)

1. Theory exam and problems. This exam will contribute 80% of the final mark. It is a prerequisite for passing the course to achieve a minimum mark of 3.5 points over 10 in this activity.
2. Laboratory practice: 20% of the final mark. In order to take this test, the student must carry out one of the experiments in the practical laboratory, randomly selected. Afterwards, he/she will present an oral report of the practical carried out.

## ADDITIONAL INFORMATION

Following the recommendations of the CRUE and the Secretariat for Inclusion and Diversity of the UGR, the systems of acquisition and evaluation of competences included in this teaching guide will be applied according to the principle of design for all people, facilitating the learning and demonstration of knowledge according to the needs and functional diversity of the students. needs and functional diversity of the students.
Información de interés para estudiantado con discapacidad y/o Necesidades Específicas de Apoyo Educativo (NEAE): Gestión de servicios y apoyos (https://ve.ugr.es/servicios/atencion-social/estudiantes-con-discapacidad).