Nanoscale Physics

2023/2024

Code: 103300
ECTS Credits: 6

Degree	Type	Year	Semester
2501922 Nanoscience and Nanotechnology	OB	4	1

Contact

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Teaching groups languages

You can check it through this link. To consult the language you will need to enter the CODE of the subject. Please note that this information is provisional until 30 November 2023.

Teachers

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Prerequisites

It is necessary to have passed Solid State and Advanced Quantum Physics subjects.

Objectives and Contextualisation

The objective of this subject is to provide the basis for the student to understand the variation of the physical properties (electronic, optical, thermal and transport) of materials on the nanometer scale.

Competences

- Adapt to new situations.
- Apply the concepts, principles, theories and fundamental facts of nanoscience and nanotechnology to solve problems of a quantitative or qualitative nature in the field of nanoscience and nanotechnology.
- Apply the general standards for safety and operations in a laboratory and the specific regulations for the use of chemical and biological instruments, products and materials in consideration of their properties and the risks.
- Communicate clearly in English.
- Communicate orally and in writing in one's own language.

- Demonstrate knowledge of the concepts, principles, theories and fundamental facts related with nanoscience and nanotechnology.
- Interpret the data obtained by means of experimental measures, including the use of computer tools, identify and understand their meanings in relation to appropriate chemical, physical or biological theories.
- Learn autonomously.
- Manage the organisation and planning of tasks.
- Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
- Operate with a certain degree of autonomy.
- Propose creative ideas and solutions.
- Reason in a critical manner
- Recognise and analyse physical, chemical and biological problems in the field of nanoscience and nanotechnology and propose answers or suitable studies for their resolution, including when necessary the use of bibliographic sources.
- Recognise the terms used in the fields of physics, chemistry, biology, nanoscience and nanotechnology in the English language and use English effectively in writing and orally in all areas of work.
- Resolve problems and make decisions.
- Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

Learning Outcomes

1. Adapt to new situations.
2. Apply the acquired theoretical contents to the explanation of experimental phenomena.
3. Communicate clearly in English.
4. Communicate orally and in writing in one's own language.
5. Correctly observe protocols for using instrumentation, reagents and chemical waste in laboratories related to the subject.
6. Critically evaluate experimental results and deduce their meaning.
7. Describe the main characteristics of two-dimensional electron gas and its properties in presence of electrical and magnetic fields.
8. Draft and present reports on the subject in English.
9. Identify and situate safety equipment in the laboratory.
10. Interpret and rationalise the results obtained in the laboratory in processes related with physics and chemistry in nanoscience and nanotechnology.
11. Interpret texts in English on aspects related with the physics and chemistry of nanoscience and nanotechnology.
12. Interpret the phenomena of absorption and emission of light in nanostructures.
13. Interpret variation in the electronic properties of solids with the dimensionality of the system on the basis of approximated band theory models.
14. Learn autonomously.
15. Manage the organisation and planning of tasks.
16. Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
17. Operate with a certain degree of autonomy.
18. Perform bibliographic searches for scientific documents.
19. Perform estimates of the physical properties of materials in systems on a nanometric scale.
20. Propose creative ideas and solutions.
21. Propose materials that have differentiated physical properties as a consequence of dimensionality.
22. Rationalise the results obtained in the laboratory in terms of physical magnitudes and their relation with the observed physical phenomena.
23. Reason in a critical manner
24. Recognise the importance of resonant phenomena in electronic transport and the emergence of thermoelectric phenomena on the nanometric scale.
25. Resolve problems and make decisions.
26. Resolve problems with the help of the provided complementary bibliography.
27. Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

Content

0. Introduction: Concepts of scale and dimensionality.

1. NANOCRYSTALS and NANOCRYSTALLINE MATERIALS obtention methods

1.1. Nucleation and Growth

1.2 From the vapour phase

1.3. From the liquid phase

1.4. From the solid phase

2. Electronic properties under confinement.

Semiconductor quantum points Model of strong links.

3. Optical properties

3.1 Semiconductors: Excitons. Emission and absorption of light.

3.2 Metallic particles: Scattering Mie and Rayleigh. Plasmons.

4. Electronic transport

Ballistic transport Formulism by Landauer-Buttiker.

5. Thermal properties

5.1 Heat capacity.

5.2 Temperature and melting of nanoparticles.

5.3 Thermal transport: Kinetic Theory. Boltzmann's equation. Ballistic phononic transport.

6. Thermoelectric phenomena

Depending on the health situation, and the need to do non-face-to-face teaching, it can be adapted.

Methodology

In this course, specific teaching is offered where there will be different formative activities that are described next. The work hours that are specified for each training activity correspond to an average student. Naturally, not all students need the same time to learn concepts and carry out certain activities, so the distribution of time should be understood as guidance. In this subject, we try to promote the active participation of the student as a relevant learning tool.

Direct training activities:

Master classes sessions: classes in which the theory teacher explains the most relevant concepts of each subject. Usually, they are blackboard classes, although in some cases classes are done with computer programs. Students have notes or copy of the transparencies in pdf format in advance uploaded in the virtual campus of the UAB.

Problems sessions: classes in which the problem teacher explains to the students how the standard problems of the subject are solved. The teacher will resolve in detail a list of selected problems and will propose to the students a list of problems that must be delivered as a mandatory task that will be part of the evaluation of the subject.

Discussion classes: discussion of selected readings (scientific articles) in direct relation to the topic of the subject will be evaluated with a presentation in class.

Laboratory practices: Students will perform laboratory practices as a learning tool.

Supervised training activities:

Tutorials: in the hours of attention to the students, the teachers will be available for the consultations of the students.

Autonomous training activities:

Problem-solving and delivery of additional problems: the student must solve the problems of the list given by the teachers. Some selected problems will be required to be delivered and will be evaluated by the professor.

Studyand preparation of exams: Personal work of the student to acquire the theoretical concepts of the subject and the abilities for the resolution of problems.

Works: students will be asked to generate a small report, in certain thematics that complement the contents of the subject. The derived marks will be part of the evaluation.

If the health situation requires a reduced attendance:

-Master sessions will be uploaded in video format, and discussed online in tutorial sessions in the scheduled hours.
-On-site sessions will be used essentially to solve problems, and to the realization of specific tutorials on the theoretical material previously supplied.
-The assistance to laboratory practices will be addapted to follow health considerations.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Lectures	28	1.12	2, 7, 19, 9, 12, 13, 21, 23, 24
Practices	6	0.24	1, 2, 6, 4, 15, 10, 16, 20, 22, 23, 27
Problems	13	0.52	1, 14, 17, 23, 26, 25
Type: Autonomous			
Study: exams, reports preparation, problem resolution	60	2.4	1, 2, 14, 6, 4, 7, 18, 19, 15, 9, 12, 10, 13, 11, 16, 17, 20, 21, 22, 23, 24, 8, 26, 25, 27, 5

Assessment

The subject will consider different types of assessment activities.

- Partial exams: Several synthesis tests will be done where the theoretical knowledge of each thematic block will be evaluated. These partial test will be programmed throughout the semester taking profit of the preset schedule for partial test. The total weight of each partials on the final mark will be 70%. If any of the partial exams does not reach the mark of 4 out of 10, it will have to be compensated in a final evaluation.

The relative weight of each partial exam will be decided based on the academic course and contents considered, but in all the cases any partial exam will exceed more than 50% of the final mark.

- Continuous and practical evaluation activities. During the course there will be different activities of continuous evaluation that will have a weight of 30% on the final note. These activities will include laboratory practices, writing reports, monographic works, presentations and delivery of problems.

Recovery. There will be a final exam of recovery where students can be examined from the parts of the suspended partials. In order to be able to get benefit from the recovery exam, the student should have participated in at least a minimum of 2/3 of the evaluation activities of the complete subject. Continuous evaluation activities are intended to evaluate the daily follow-up of the subject and therefore, as in the case of laboratory practices, they can not be recovered.

Depending on health scenario the evaluation will be adapted.

Unique Evaluation.

Theoretical Exams (70%)

Students who have opted for the unique evaluation method will have to take a final test that will consist of an exam on the content covered in the different partial exams throughout the course. This exam will account for 70% of the final grade (equivalent to the weight of the partial exams in regular evaluation) and will be scheduled on the date of the second partial exam, with an extended timeframe. If the score on this exam is below 4 out of 10, the student will have to take a recovery exam.

Practical Assignments (15%) and Continuous Assessment Tasks (15%)

Students who have chosen the unique evaluation method must complete the mandatory practical assignments, which account for 15% of the final grade. One or more practice groups will be designated exclusively for students under the unique evaluation method. These students must complete the practical assignments in-person during the first or second scheduled session. The reports for both assignments will be submitted individually on the same day as the exam (scheduled for the second partial). Additionally, on the same day, students will submit individual tasks solving a set of selected problems, accounting for 5% of the grade, and an individual presentation of a scientific article related to the subject recorded on video, accounting for 10% of the grade. The practical assignments and task submissions are not recoverable.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Continuous Assessment: Practices, problems, reports	30%	34	1.36	1, 14, 6, 3, 4, 18, 19, 15, 10, 11, 16, 17, 20, 22, 23, 8, 26, 25, 27, 5
EXAMS	70%	9	0.36	1, 2, 7, 19, 9, 12, 13, 21, 23, 24, 25

Bibliography

The physics of low-dimensional semiconductors. J. H. Davies. Cambridge University Press. 1998.

Electronic transport in mesoscopic systems, S. Datta, Cambridge University Press, 1995.

Nanoscale energy transport and conversion : a parallel treatment of electrons, molecules, phonons, and photons. G. Chen, Oxford University Press, 2005.

Software

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