UAB
Universitat Autònoma de Barcelona

Nanomaterial Physics

2023/2024

Code: 100184
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	2

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

Cristian Rodriguez Tinoco

Marta Gonzalez Silveira

Prerequisites

It is recommendable, although not mandatory, to have taken *Solid State Physics* previously.

Objectives and Contextualisation

This course intends to provide the students with the fundamentals to be able to understand how do the physical properties (electronic, optical, thermal, magnetic and transport) of the materials change when reduced to nanometric scale.

Competences

- Act with ethical responsibility and respect for fundamental rights and duties, diversity and democratic values.
- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals

- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- Plan and perform, using appropriate methods, study, research or experimental measure and interpret and present the results.
- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation
- Using appropriate methods, plan and carry out a study or theoretical research and interpret and present the results
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Calculate and analyse the characteristics of two-dimensional electron gas.
2. Calculate the absorption and emission of light in semiconductor nanoparticles.
3. Calculated band diagrams in low-dimensional systems.
4. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
5. Correlate changes in physical properties at the nanoscale with the development of new devices.
6. Explain the explicit or implicit code of practice of one's own area of knowledge.
7. Identify changes in physical properties on decreasing size to nanoscale.
8. Identify situations in which a change or improvement is needed.
9. Identify the basic principles of electron and phononic transport for their subsequent application in advanced low-dimensional systems.
10. Identify the importance of dimensionality ein the electronic, thermal, optical, magnetic and transport properties of materials.
11. Identify the social, economic and environmental implications of academic and professional activities within one's own area of knowledge.
12. Interpret the simplification of transport equations in the ballistic limit.
13. Measure the luminescence of semiconductor quantum dots.
14. Obtain simplified models of energy bands to describe the electronic behaviour of low-dimensional solids.
15. Provide fuller description of radiation-matter interaction in manometric systems.
16. Rationalize the results obtained in the laboratory with regard to the physical phenomena observed, considering the influence of dimensionality on experimental measurements.
17. Relate dimensionality with dimensions characteristic of nanoscale particles.
18. Simulate transport properties through analogies with electronic circuits.
19. Use Landauer's formulism to describe ballistic transport.
20. Use calculus in one and several variables, in addition to differential equations and matrix calculus in the study of the physical properties of nanomaterials.
21. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
22. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
23. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

24. Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals

Content

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. SIZE effects on the physical properties.

2.1 Electronic properties: 1D, 2D and 3D confinement

2.1.1. Linear or circular chain of carbon atoms.

2.1.2. Particles in square wells.

2.1.3. Band structure and density of states as a function of dimensionality.

2.1.4. Confinement in the presence of an electric field: triangular potential well.

2.1.5. Confinement in the presence of a magnetic field: parabolic potential well.

2.1.5.1. Landau levels. Quantum Hall effect.

2.2. Electronic transport

2.2.1 Balistic transport: Landauer formulism

2.2.2. Tunnel transport: step function. Square barrier. Current in 1D. Resonant tunnel effect. Tunnelling in heterostructures.

2.2.3 Applications: Electronic and magnetic devices based on heterostructures.

2.3. Optical properties

2.3.1 Excitons: coulomb interactions.

2.3.2 Light emission and absorption (interband, intersubband).

2.3.3 Technological applications.

2.4. Thermal properties

2.4.1 Heat Capacity

2.4.2 Melting temperature and enthalpy in metallic and semiconductor nanoparticles.

2.4.4 Thermal transport.

2.4.5 Seebeck and Peltier effects.

Methodology

This course offers specific contents about physics at the nanoscale. A list of the learning activities used to teach the course is detailed in the following lines. The working hours corresponding to each activity are just a guide and have been calculated for an average student. In this course we try to encourage students to participate in an active way, as part of the learning process.

Guided learning activities:

Lectures: the lecturer will explain the most relevant concepts of each of the topic of the course. Normally, this type of class is carried out on the blackboard, although slides will be used in some occasions. The students will have the notes for the different topics in advance.

Practicum: In these classes, the teacher will explain how to solve some sample problems. From the whole list, only part of the exercises will be solved in class. From this same list, the teacher will ask the students to deliver one of the problems from each topic. This is a mandatory activity, as it is part of the evaluation.

Discussion class: The students will have to read a scientific article related to each of the topics from the course. Some of the classes will be dedicated to discussing the contents of each of these articles altogether.

Laboratory: The students will perform some laboratory practices as part of the learning activities.

Supervised learning activities:

Tutorials: during the attention hours, the lecturers of the course will be available for any type of questions and doubts related to the different topics of the course.

Autonomous learning activities:

Problem solving and deliveringof extra exercises: the student will have to solve the problems from the list that the teacher will specify. The students can also solve some extra exercises to improve their mark.

Study and exam preparation: Individual work from the student with the aim of acquiring the theoretical concepts from the course and the necessary skills to solve the problems.

Extra activities: the students have the opportunity to perform some extra projects, which will require a certain level of code programming, where they can solve some problems related to the different topics of the subject.

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			
Laboratory	7	0.28	
Lectures	27	1.08	
Practicum	12	0.48	
Scientific articles discussion	3	0.12	
Type: Autonomous			

Exercise solving and extra exercises delivering	17	0.68
Extra materials preparation	20	0.8
Study and exam preparation	51	2.04
Tutorials	5	0.2

Assessment

Problem solving and article reading: 10 % of the final mark.

Practicum (realization, report, interview): 10 % of the final mark.

First exam: 40% of the final mark.

Second exam: 40% of the final mark.

(2nd chance) Exam: 80% of the final mark. (Only the students that have been previously evaluated or 2/3 of the evaluation will have the chance to do this exam)

Single evaluation modality

Students who decide to join the option of single assessment modality must take a final test that will consist of an exam of the syllabus of the entire subject, to be carried out on the day that the rest of the students take the second exam of the continous evaluation. The grade obtained in this test will represent the 80% of the final mark.

The laboratory sessions and laboratory reports are mandatory (10% of the final mark), as well as the different exercises from continous evaluation (10% of the final mark). The difference in this case will be that everything will be handled the day of the exam.

If the final mark does not reach 5, this student has another opportunity to pass the subject through the extra exam that will be held on the date set by the deputy coordination of the degree. The grade obtained in this second exam will correspond to a 80% of the final mark.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exercises delivering and article reading	10%	0	0	15, 3, 1, 2, 4, 5, 6, 24, 9, 10, 11, 7, 8, 12, 14, 21, 17, 18, 22, 23, 20, 19
Partial exam I	40%	2	0.08	3, 1, 4, 5, 6, 10, 11, 7, 8, 12, 14, 21, 17, 18, 22, 20, 19
Partial exam II	40%	2	0.08	15, 2, 5, 6, 9, 10, 11, 7, 8, 12, 14, 17, 18, 20, 19
Partial exams (2nd chance)	80%	3	0.12	15, 3, 1, 2, 4, 5, 6, 9, 10, 11, 7, 8, 12, 14, 21, 17, 18, 22, 20, 19
Practicum	10%	1	0.04	15, 2, 4, 5, 24, 9, 10, 11, 7, 8, 13, 16, 21, 17, 22, 23, 20, 19

Bibliography

Solid State Physics, N.W.Ashcroft, N.D. Mermin, Saunders College Publishing.

The Physics of Low dimensional semiconductors: An introduction, J.H.Davies, Cambridge University Press, 1997.

Quantum semiconductor structures: Fundamentals and applications , C.Weisbuch, B.Vinter, Academic Press, 1991.

Nanomaterials: Synthesis, Properties and Applications, Ed. A. S. Edelstein, R. C. Cammarata, Institute of Physics, 1998.

The atomistic nature of crystal growth, B.Mutaftschiev,... Springer-verlag, 2003.

Software

No specific software is required.