2022/2023

Information and Communication Nanotechnology

Code: 103295
ECTS Credits: 6

Degree	Type	Year	Semester
2501922 Nanoscience and Nanotechnology	OT	4	1

Contact

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Use of Languages

Principal working language: catalan (cat)

Some groups entirely in English: No

Some groups entirely in Catalan: Yes

Some groups entirely in Spanish: No

Other comments on languages

Some lectures given in Spanish. Some course materials will be in English.

Teachers

Jordi Suñé Tarruella

Prerequisites

Basic knowledge of Quantum Mechanics, electronic devices and solid state physics is required.

Objectives and Contextualisation

- Identifying the physical limits of present day information processing technologies, and knowing the alternatives proposed from nanotechnology.
- Knowing the foundations of the different approaches to electron transport in devices.
- Describing the working principles of nanoelectronic, nanophotonic and spintronic devices.

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.
- 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. Build simple numerical simulators and apply them to the modelling of electronic, magnetic, thermal, optical and mechanical devices on the nanometric scale.
4. Communicate clearly in English.
5. Communicate orally and in writing in one's own language.
6. Correctly use specific physical and electronic simulation programs to study electronic devices.
7. Critically evaluate experimental results and deduce their meaning.
8. Describe the basics of the interaction between matter and light on the nanometric scale and the main nanophotonic devices.
9. Describe the main tools and methods for the optical manipulation of nanometric objects.
10. Describe the operation of the main nanoelectronic devices: resonant tunnel diodes, punctual contacts, quantum dots, single electron transistors and those based on nanotubes and nanophylls, spin devices...
11. Describe the principles of molecular electronics.
12. Describe the principles of plasmonics.
13. Describe the socioeconomic impact of new electronic, magnetic and photonic devices in information and communication technologies.
14. Describe the typologies of magnetic nanostructures and their properties and identify the principles of spintronics.
15. Design basic electronic devices, establishing their relation with manufacturing technology (including materials, dimensions and doping) with their specifications on an electrical level
16. Draft and present reports on the subject in English.
17. Identify the physical limits of CMOS technology and describe current trends in nanoelectronics.
18. Interpret texts in English on aspects related with the physics and chemistry of nanoscience and nanotechnology.
19. Learn autonomously.
20. Manage the organisation and planning of tasks.
21. Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
22. Operate with a certain degree of autonomy.
23. Perform bibliographic searches for scientific documents.
24. Propose and design nanoelectronic, nanomagnetic and nanophotonic devices in accordance with specifications and in consideration of technology.
25. Propose creative ideas and solutions.
26. Reason in a critical manner
27. Recognise the need for multi-scale treatment in the simulation of electronic transport in devices of nanometric dimensions.
28. Resolve problems and make decisions.
29. Resolve problems with the help of the provided complementary bibliography.
30. Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

Content

1. Electronic transport and simulation of electronic devices

Foundations of semiconductor devices. Effective mass equation. Boltzmann transport equation. Monte Carlo simulation of transport in devices.

2. Charge based nanoelectronic devices

The MOS transistor. Evolution of semiconductor device technology (ITRS and IRDS). Memories. Quantum effect devices (RTD, point contacts). Single electron devices. Advanced field effect devices. Molecular electronics.

3. Photonic and optoelectronic devices

Isomorphism between Maxwell and Schrödinger equations. Photonic crystals, defects, waveguides and Anderson localization. Optical transitions and selection rules in semiconductors. Lasers basead in nanostructures (quantum well and dot, VCSELs, quantum cascade...). Entangled photons for quantum cryptography. Nanophotonics and the market.

4. Spinbased nanoelectronic devices

Dynamics of single spins and spins in solids. Spin valves and giant magnetoresistance. Hard drive read heads, circuit couplers. Spin-transfer torque. Magnetic RAM memories (MRAMs). Spin injection into semiconductors. Spin relaxation mechanisms in semiconductors. Spin transistors. Spin based quantum computing.

Methodology

Formation will be based on magistral lectures complemented with practical classroom and laboratory sessions. There will be autonomous activities including problem solving and the critical reading of texts.

Magistral lectures and problem and lab sessions may be online depending on the evolution of the health situation.

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			
Classroom practical sessions	10	0.4	2, 7, 5, 3, 21, 24, 25, 26, 27, 29, 28, 6
Laboratory sessions	8	0.32	1, 2, 7, 4, 3, 20, 21, 22, 24, 25, 26, 16, 28, 30, 6
Magistral lectures	30	1.2	5, 10, 8, 11, 12, 13, 9, 14, 17, 25, 26, 27
Type: Autonomous			
Problem set solving and lab reports	50	2	1, 2, 19, 7, 4, 5, 3, 23, 20, 18, 21, 22, 24, 25, 26, 16, 29, 28, 6
Study of theoretical foudations	48	1.92	1, 19, 10, 8, 11, 12, 13, 9, 14, 23, 20, 17, 18, 21, 22, 26, 27

Assessment

The complention of the lab sessions is compulsory, and students must pass the lab sessions separately.

In order to pass the course a minimum grade of 4 in the synthesis test is required. This can be obtained:

a) When the mean of the synthesis partial tests reaches a 4, and none of the partial tests has a qualification below 2.

b) When the synthesis retake test reaches the minimum of 4.

The student must have sat in the two partial synthesis tests and passed the lab sessions in order to be allowed to retake the synthesis test.

"Matrícula d'honor" will be awarded with preferent attention to the results of the synthesis partial tests over the second chance synthesis test. Sitting on the second chance synthesis test to obtain a better grade is possible, but in case the grade of that test is lower than the grade of the mean of the partial tests, the final synthesis grade will be the mean between the average of the partial test and the grade of the second chance synthesis test.

Synthesis tests may be substituted by additional problem sets and independent work if authorities determine that on site exams are not permitted.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Laboratory sessions	25%	0	0	1, 2, 19, 7, 4, 3, 20, 21, 22, 24, 25, 26, 16, 28, 30, 6
Problem sets and independent work	20%	0	0	7, 5, 23, 20, 18, 21, 22, 26, 29, 28, 30
Synthesis test	55%	4	0.16	5, 3, 10, 8, 11, 12, 13, 9, 14, 15, 17, 26, 27, 28

Bibliography

S. V. Gaponenko

Introduction to Nanophotonics

Cambridge University Press (2010)

P.N. Prasad

Nanophotonics

Wiley (2004)

Y. Tsividis and C. McAndrew

Operation and Modeling of the MOS Transistor

Oxford University Press (2010)

S.M Sze and K.K. Ng

Physics of Semiconductor Devices

Wiley (2007)

J. Burghartz

Guide to State-of-the-Art Electron Devices

Wiley (2013)

R. Waser

Nanoelectronics and Information Technology

Wiley (2005)

S. Bandyopadhyay and M. Cahay

Introduction to spintronics

CRC Press (2008)

M. Lundstrom

Fundamentals of carrier transport

Cambridge University Press (2009)

Software

One of the labs will make use of Matlab/Octave.