COURSE SHEETS

Master study program	**PHYSICS OF ADVANCED MATERIALS AND NANOSTRUCTURES / FIZICA MATERIALELOR AVANSATE ȘI NANOSTRUCTURI**
Academic field	**PHYSICS**
Faculty	**FACULTY OF PHYSICS**
Duration	**2 years (4 semesters)**
Type of study full-time(IF)/ part-time (IFR)/ distance-learning (ID)	**full-time (IF)**
Accredited: 2013 **Revised: 2019** **Applies begining with: autumn 2020**	

Table of Contents

I. Compulsory course units

DI.101 Quantum Statistical Physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	Theoretical and Computational Physics (in English)
1.7. Study mode	Full-time study

2. Course unit

2.1. Course unit title	Quantum Statistical Physics							
2.2. Teacher				Prof. Dr. Virgil Baran				
2.3. Tutorials/Practicals instructor(s)				Lect. Dr. Victor Dinu				
2.4. Year of study	I	2.5. Semester	1	2.6. Type of evaluation	E	2.7. Type of course unit	Content[1)]	**DA**
							Type[2)]	**DI**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: Lecture	2	Practicals/Tutorials	2
3.2. Total hours per semester	56	Lecture	28	Practicals/Tutorials	28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	30
3.2.4. Preparation for exam	4
3.2.5. Other activities	0

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Classical Statistical Mechanics, Equations of Mathematical Physics
4.2. competences	Knowledge about: mechanics, thermodynamics, algebra, solving differential equations

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Video projector
5.2. for practicals/tutorials	

6. Specific competences acquired

Professional competences	• Identify and proper use of the main physical laws and principles in a given context: the use of the concepts of quantum statistical physics • Solving problems of physics under given conditions • Use of the physical principles and laws for solving theoretical or practical problems with qualified tutoring • Rigorous knowledge of quantum theory, concepts, notions and problems in the area of many-body systems at finite temperature • Ability to use this knowledge in various branches of physics
Transversal competences	• Efficient use of sources of information and communication resources and training assis-tance in a foreign language • Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Understanding the fundamental aspects related to the study of quantum statistical physics
7.2. Specific objectives	Assimilation of formalism of quantum statistical theory: concepts, methods of statistical ensambles, quantum distributions. Explaining the peculiar fenomena of quantum domain, which have no classical analogue. Acquire the skills to describe and calculate the physical properties of quantum systems involved in different physical conditions.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Quantum states. Microstates and macrostates of a quantum system. Statistical (density) operator: definition and properties. Time evolution.	Systematic exposition - lecture. Examples	2 hours
Quantum entropy. Boltzmann-von Neumann formula. Physical interpretation. Principle of maximum entropy. Equilibrium distributions. Statistical operator in equilibrium. Boltzmann-Gibbs formula.	Systematic exposition - lecture. Examples	4 hours
Partition functions: definition and properties. Entropy in thermodynamic equilibrium, natural variables. Equilibrium statistical ensembles. Ensemble averages. Canonical, grand-canonical and microcanonical ensembles.	Systematic exposition - lecture. Examples	4 hours
The indistinguishability of quantum particles. Occupations number representation. Pauli principle. Applications.	Systematic exposition - lecture. Examples	6 hours
Grand-canonical partition functions for systems of independent fermions. Fermi-Dirac statistics. Applications.	Systematic exposition - lecture. Examples	2 hours
Grand-canonical partition functions for systems of independent bosons. Bose-Einstein statistics. Applications.	Systematic exposition - lecture. Examples	2 hours

Equilibrium radiation, Planck law. The black-body radiation. Applications.	Systematic exposition - lecture. Examples	4 hours
Quantum liquids. Helium three. Helium four and Bose-Einstein condensation.	Systematic exposition - lecture. Examples	4 hours

Bibliography:

1. R. Balian, From Microphysics to Macrophysics Vol. 1, 2, Springer 2006
2. L.D. Landau, E.E. Lifsit, Fizică Statistică, Editura Tehnică
3. K. Huang, Statistical Mechanics, John Wiley & sons, 1987
4. Radu Paul Lungu, Elemente de mecanica statistica cuantica, Editura UB, 2017.

8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
The statistical thermodynamics of the ideal fermionic gas. White dwarf stars. Neutron stars.	Problem solving	6 hours
The statistical thermodynamics of the ideal bosonic gas.	Problem solving	6 hours
Statistical mechanics of lattice vibrations. Phonons. Debye model.	Problem solving	4 hours
Heisenberg model and applications.	Problem solving	4 hours
Landau two-fluids model. Maxon-roton spectrum.	Problem solving	4 hours
Linear response. Fluctuation-dissipation theorem.	Problem solving	4 hours

Bibliography:

1. R. Balian, From Microphysics to Macrophysics Vol. 1, 2, Springer 2006
2. D. Dalvit, J. Frastai, I. Lawrie, *Problems on statistical mechanics*, IOP 1999.
3. Radu Paul Lungu, Elemente de mecanica statistica cuantica, Editura UB, 2017

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical competences, which are fundamental for a Master student in the field of modern physics, corresponding to national and international standards. The contents is in line with the requirement of the main employers of research institutes and universities.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test and oral examination	60%
10.5.1. Tutorials	- Ability to use specific problem solving methods	Homeworks	40%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) At least 50% of exam score and of homeworks.			

Date 10.06.2019	Teacher's name and signature Prof. dr. Virgil Baran	Practicals/Tutorials instructor(s) name(s) and signature(s) Lect. dr. Victor Dinu

Date of approval
10.06.2019

Head of Department

Prof.dr. Virgil Baran

DI.102 Condensed Matter Physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Condensed Matter Physics**							
2.2. Teacher	Prof. dr. Daniela Dragoman							
2.3. Tutorials instructor(s)	Lect. dr. Sorina Iftimie							
2.4. Practicals instructor(s)								
2.5. Year of study	1	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	30
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics
4.2. competences	Computational physics abilities

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	-

6. Acquired specific competencies

Professional competencies	**4.** Identification and adequate use of the specific laws and concepts of condensed matter physics in a given context **5.** Solving physics problems in given conditions **6.** Creative use of acquired knowledge for understanding and modelling of physical processes and properties of condensed matter **7.** Analysis and communication of scientific data, communication for physics popularisation.
Transversal competencies	**8.** Efficient use of scientific information and communication resources for professional formation in English. **9.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and analysis of the specific physical processes in condensed matter
7.2. Specific objectives	Study of transport phenomena and of the associated scattering mechanisms. Highlighting at each chapter the applications of the studied phenomena and some problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introduction: kinetic Bltzmann equation; relaxation time approximation; scattering mechanisms	Systematic exposition - lecture. Examples.	2 hours
Scattering of charge carriers on ionized and neutral impurities. Relaxation time calculation	Systematic exposition - lecture. Examples.	4 hours
Scattering of charge carriers on phonons in nonpolar and polar crystals. Relaxation time calculation	Systematic exposition - lecture. Examples.	4 hours
Electrical resistivity of metals, alloys and semiconductors. Dependencies on temperature and concentraion of impurities/defects	Systematic exposition - lecture. Examples.	2 hours
Fundamental transport coefficients. Thermal conductivity of conductors. Lorentz number. Thermal conductivity of isolators	Systematic exposition - lecture. Examples.	4 hours
Thermoelectic effects. Materials' figure of merit	Systematic exposition - lecture. Examples.	2 hours
Onsager relations. Thermo- and galvanomagnetic effects. Spin effects. Spin-orbit coupling	Systematic exposition - lecture. Examples.	4 hours
Dielectric properties of the electron gas. Plasmons	Systematic exposition - lecture. Examples.	2 hours
Electron-electron interactions. Fermi liquid theory. Hubbard model	Systematic exposition - lecture. Examples.	2 hours
Polaritons. Electron-phonon interactions. Polarons	Systematic exposition - lecture. Examples.	2 hours

References:

5. Yu. M. Galperin, Introduction to Modern Solid State Physics, Lecture notes https://folk.uio.no/yurig/fys448/f448pdf.pdf
6. C. Kittel, *Introduction to Solid State Physics*, 8th Ed., 2005, Wiley
7. N.W. Ashcroft, N.D. Mermin, *Solid State Physics*, Saunders College, 1976.
8. I. Licea, Fizica stării solide, partea I, Universitatea Bucureşti 1991
9. D. Dragoman, Lecture notes

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Scattering of charge carriers on ionized impurities. Classical model. Relaxation time calculation	Exposition. Guided work	2 hours
Solutions of the kinetic Boltzmann equation in different conditions of nonequilibrium. Moments of the kinetic Boltzmann equation	Exposition. Guided work	4 hours
Solutions of the kinetic Boltzmann equation in ambipolar conductors in different conditions of nonequilibrium	Exposition. Guided work	4 hours
Charge transport in low-dimensional conductors	Exposition. Guided work	4 hours
Thermoelectric effect. Mott formula. Influence of dimensionality	Exposition. Guided work	4 hours
Heat transport. Fourier versus Boltzmann equation for phonons	Exposition. Guided work	4 hours
Spin-orbit coupling. Rashba and Dresselhaus effects	Exposition. Guided work	4 hours
Bulk/volume plasmons and surface plasmon polaritons	Exposition. Guided work	2 hours

Bibliography:

1. C. Kittel, *Introduction to Solid State Physics*, 8th Ed., 2005, Wiley
2. N.W. Ashcroft, N.D. Mermin, *Solid State Physics*, Saunders College, 1976.
3. Yu. M. Galperin, Introduction to Modern Solid State Physics, Lecture notes https://folk.uio.no/yurig/fys448/f448pdf.pdf

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	4 ore

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

Bibliography:

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this course is similar to that of other courses taught at Romanian (Univ. Babeş-Bolyai, Cluj) and foreign (Berkeley University, USA, University of Sheffield, UK, University of Oslo) universities, and is designed such that the student develops abilities of modeling the charge, heat and/or spin transport in condensed matter, and the interactions of solid materials with the electromagnetic field, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Clarity, coherence and concision of exposition;	Written exam	67%

	- Correct use of physical models and of specific mathematical methods; - Ability to exemplify		
10.5.1. Tutorials	- Use of specific physical and mathematical methods for solving a given problem;	Written exam	33%
10.5.2. Practicals			
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Daniela Dragoman	Lect. dr. Sorina Iftimie

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.103 Group theory with applications in physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	Theoretical and Computational Physics (in English)
1.7. Study mode	Full-time study

2. Course unit

2.1. Course title	Group theory with applications in physics							
2.2. Teacher			Lect. dr. Victor Dinu					
2.3. Tutorials instructor(s)			Lect. dr. Victor Dinu					
2.4. Practicals instructor(s)								
2.5. Year of study	1	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DA**
							Type[2)]	**DI**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: Lecture	2	Practicals/Tutorials	0/2
3.2. Total hours per semester	56	Lecture	28	Practicals/Tutorials	0/28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	25
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	35
3.2.4. Preparation for exam	4
3.2.5. Other activities	0

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Linear algebra, Quantum mechanics
4.2. competences	Knowledge about: mechanics, atomic physics, solid state physics, nuclear physics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Video projector
5.2. for practicals/tutorials	

6. Specific competences acquired

Professional competences	4. Ability to use knowledge on group theory in various branches of physics 5. Ability of analyse and interpret experimental data, formulate rigorous theoretical conclusions. 6. Ability to employ mathematical models based on symmetries to describe the physical phenomena. 7. Ability to evidence the relation between irreducible representations and invariant subspaces of Hilbert space ; evidence the connection between energy spectrum and irreducible representations.
Transversal competences	Efficient use of scientific information resources and of communication and of resources for professional formation in English. Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Understanding the fundamental aspects related to the study of symmetries in physics. Expose the basic properties of groups and their matrix representations. The study of the role of group theory in quantum mechanics.
7.2. Specific objectives	Assimilation of the formalism of group theory: concepts, methods, representations. Acquire the skills to describe and calculate the physical properties of physicsl systems based on symmetries.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Introductory notions: symmetries of a physical system, the role of group theory in physics, groups clasification.	Systematic exposition - lecture. Examples	1 hours
Group axioms, group multiplication table, subgroups,mappings of groups, direct product of groups.	Systematic exposition - lecture. Examples	1 hours
Conjugate elements, equivalence classes, invariant subgroups, cosets, quotient group	Systematic exposition - lecture. Examples	1 hours
Matrix representation of a group, equivalent representations, irreducible representation. Schur lemma’s.	Systematic exposition - lecture. Examples	1 hours
Orthogonality relations for irreducible representations of a finite group, inequivalent representations for finite groups, characters and their orthogonality relations, character table.	Systematic exposition - lecture. Examples	2 hours
Group theory and quantum mechanics. From degeneracy to group representations: classification of the eigenvalues and of the eigenstates of energy according to the irreducible representations of symmetry group. Applications.	Systematic exposition - lecture. Examples	2 hours
Discrete symmetries. Rotation group in quantum mechanics. Tensor operators. Wigner-Eckart theorem. Aplications in atomic and nuclear physics.	Systematic exposition - lecture. Examples	4 hours

Basis functions of irreducible representations. Product of representations	Systematic exposition - lecture. Examples	2 hours
Curie-Neumann symmetry principle. Fundamental theorem of symmetry. Applications	Systematic exposition - lecture. Examples	2 hours
Symmetry of material tensors. 2-nd and 3-rd order tensors.	Systematic exposition - lecture. Examples	4 hours
Space groups. Group of the wave vector. Irreducible representations of space groups.	Systematic exposition - lecture. Examples	4 hours
Energy band models based on symmetry	Systematic exposition - lecture. Examples	4 hours

Bibliography:

10. J.F. Corwell, *Group theory in physics. An Introduction*. Academic Press, 1997.

11. A. Zee, *Group theory in a nutshell for physicist*, Princeton University Press, 2017

12. W.K. Tung, *Group theory in physics*, World Scientific, 1985

13.

8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Basic group theory. Applications.	Problem solving	1 hours
Discrete groups representations.	Problem solving	1 hours
Permutation groups. Dihedral groups.	Problem solving	2 hours
Group theory and harmonic motion.	Problem solving	2 hours
Unitary representations for rotations, Wigner matrices, Spherical tensors.	Problem solving	4 hours
Discrete translations.	Problem solving	2 hours
Symmetry of material tensors. Applications	Problem solving	4 hours
Applications to lattice vibrations	Problem solving	6 hours
k·p perturbation theory. Applications	Problem solving	6 hours

Bibliography:

10. A. Zee, *Group theory in a nutshell for physicist*, Princeton University Press, 2017

11. W.K. Tung, *Group theory in physics*: *Problems and solutions*, World Scientific, 1991

12. S. Sternberg, *Group theory and physics*, Cambridge University Press, 1994

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

First course unit develops some theoretical competences, which are fundamental for a Master student in the field of modern physics, corresponding to national and international standards. The contents is in line with the requirement of the main employers of research institutes and universities.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test/oral examination	60%
10.5.1. Tutorials	- Ability to use specific problem	Homeworks	40%

	solving methods		
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) At least 50% of exam score and of homeworks.			

Date
10.06.2019

Teacher's name and signature

Lect. dr. Victor Dinu

Practicals/Tutorials instructor(s) name(s) and signature(s)

Lect. dr. Victor Dinu

Date of approval
10.06.2019

Head of Department

Prof.dr. Virgil Băran

DI.104 Experimental methods in Physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Experimental methods în Physics**							
2.2. Teacher	Conf. dr. Vasile Bercu							
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)	Conf. dr. Vasile Bercu, Prof. dr. Alexandru Jipa, Lect. dr. Adriana Bălan, Lect. dr. Ovidiu Toma, Conf. dr. Cristian Necula							
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	5	distribution: lecture	2	Tutorials/Practicals	0/3
3.2. Total hours per semester	70	distribution: lecture	28	Tutorials/Practicals	0/42
Distribution of estimated time for study					hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography					25
3.2.2. Research in library, study of electronic resources, field research					25
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks					26
3.2.4. Examination					4
3.2.5. Other activities					

3.3. Total hours of individual study	76
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Electricitate și magnetism, Optică, Fizica solidului I, Electrodinamică, Mecanică cuantică
4.2. competences	8. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	- research infrastructure for morphological, optical, magnetic and microstructural characterizations

6. Acquired specific competencies

Professional competencies	**13.** Use of methods for morphological, optical, magnetic and microstructural characterizations. **14.** Knowledge of physics of interaction of radiation with matter **15.** Creative use of acquired physical knowledge related to morphological, optical, magnetic and microstructural characterizations. **16.** Analysis and communication of scientific data, communication for physics popularisation. **17.** Use of specific software tools.
Transversal competencies	**18.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **19.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction to techniques for microstructural, morphological, magnetic and optical characterizations of materials
7.2. Specific objectives	Study of magnetic properties of materials AFM studies of surface morphology Measuring optical coefficients of thin films Micro-structural studies based on ion beams Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking în solving problems.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Atomic force microscopy (AFM) – physical principles. Working modes (non-contact, contact). Characterization of surface morphology. Magnetic force microscopy (MFM), Scanning tunneling microscopy (STM). Applications	Systematic exposition - lecture. Examples.	6 hours
Electron spin resonance. Investigation of defects în semiconductors.	Systematic exposition - lecture. Examples.	6 hours
Ellipsometry. Physical principles. Optical coefficients of thin films.	Systematic exposition - lecture. Examples.	6 hours
Magnetic propeties of condensed systems. Vibrating Sample Magnetometer and measurement of magnetic susceptibility at room temperature. Temperature effects on magnetic properties.	Systematic exposition - lecture. Examples.	4 hours
Characterization techniques of condensed systems using accelerated ion beams (RBS, ERDA, PIXE). Applications.	Systematic exposition - lecture. Examples.	6 hours
References: **14.** M. Nastasi, J.W. Mayer, Y. Wang, *Ion beam analysis – Fundamentals and applications* (CRC Press,		

Boca Raton, USA, 2015).
15. M. Fox, *Optical properties of solids* (Oxford University Press, Oxford, UK, 2001).
16. C. Necula, *Determinarea proprietăţilor magnetice ale rocilor pe baza histerezisului magnetic* (Ars Docendi, Bucureşti, 2017),
17. J.A. Weil, J.R. Bolton, *Electron paramagnetic resonance* (Wiley, New Jersey, USA, 2007)

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Bibliography:		

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
AFM in contact and non-contact mode. Surface morphology characterizations	Guided practical work	6 hours
MFM experiments	Guided practical work	3 hours
Characterization of magnetic domains by FORC (First Order Reversal Curves) and Preisach diagrams, using PMC VSM 3900 system. Distribution of magnetic particles from susceptibility measurements.	Guided practical work	6 hours
Determination of blocking temperature and of the temperature dependent coercitive force.	Guided practical work	6 hours
Ellipsometric measurements. Dispersion of optical coefficients of thin films.	Guided practical work	6 hours
Electron spin resonance. Characterization of structural defects în semiconductors.	Guided practical work	6 hours
Characterization of microstructure of condensed systems using accelerated ion beams (RBS, ERDA, PIXE)	Guided practical work	9 hours

8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union. The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyse specific examples;	Written and oral exam	50%

10.5.1. Tutorials	- Use of specific physical and mathematical methods and techniques;		
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	50.00%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Conf. dr. Vasile Bercu	Prof. dr. Alexandru Jipa Conf. dr. Vasile Bercu Conf. dr. Cristian Necula Lect. dr. Adriana Bălan Lect. dr. Ovidiu Toma

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.106 Research activity

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title		**Research activity**							
2.2. Teacher									
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)		Prof. dr. Lucian Ion							
2.5. Year of study	1	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**	
							Type[2]	**DI**	

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	0	Tutorials/Practicals	0/4
3.2. Total hours per semester	56	distribution: lecture	0	Tutorials/Practicals	0/56

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	0
3.2.2. Research in library, study of electronic resources, field research	5
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	10
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	15
3.4. Total hours per semester	75
3.5. ECTS	3

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics, Electrodynamics, Thermodynamics and statistical physics
4.2. competences	Using of specialized software for scientific data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	Research infrastructure (în research centers) for preparation and characterization of materials and nanostructures

6. Acquired specific competencies

Professional competencies	**20.** Creative use of acquired knowledge for preparation and characterization of materials and nanostructures **21.** Solving physics problems in given conditions **22.** Analysis and communication of scientific data, communication for physics popularisation. **23.** Use of professional software
Transversal competencies	**24.** Efficient use of scientific information and communication resources for professional formation in English. **25.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and use of experimental or theoretical methods used în fabrication and/or characterization of materials and nanostructures
7.2. Specific objectives	Highlighting of specific problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
	Systematic exposition - lecture. Examples.	
References: **18.**		

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
	Exposition. Guided work	
Bibliography: 9.		

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	
Bibliografie: 1.		

8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Experimental methods used in fabrication and/or characterization of materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student
Theoretical models for description of physical properties/physical phenomena related to materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student

Bibliography:
- to be indicated by the coordinator of the research activity

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this discipline unit is related to research themes proposed to students and is designed such that the student develops abilities of investigating the physical properties of materials and nanostructures, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture			
10.5.1. Tutorials			
10.5.2. Practicals			
10.5.3. Project [if applicable]	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Knowledge of experimental techniques - Ability to analyse scientific data	Research report	100%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Final mark reflects the assessment of the coordinator of the research activity and is related to the knowledge level of experimental/theoretical models used and to the correct interpretation of scientific data.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.107 Materials characterization techniques

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Materials characterization techniques**							
2.2. Teacher	Prof. dr. Lucian Ion							
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)	Prof. dr. Lucian Ion							
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	25
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	35
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics, Electrodynamics
4.2. competences	Computational physics abilities

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	Research infrastructure for structural/optical characterization

6. Acquired specific competencies

Professional competencies	**26.** Identification and adequate use of the specific laws and concepts of condensed matter physics in a given context – knowledge of crystalline structure of (nano)materials **27.** Creative use of acquired knowledge for understanding and modelling of structural and optical properties of condensed matter **28.** Solving physics problems in given conditions **29.** Analysis and communication of scientific data, communication for physics popularisation.
Transversal competencies	**30.** Efficient use of scientific information and communication resources for professional formation in English. **31.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Analysis of structural and optical properties of (nano)materials
7.2. Specific objectives	Study of crystalline structure of materials Description of experimental techniques for structural investigations based on scattering of X-rays and thermal neutrons Study of optical transitions în semiconductors Highlighting of specific problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Generation and properties of X-rays	Systematic exposition - lecture. Examples.	2 hours
Crystalline structures. Symmetry properties. Classification. Point groups. Space groups.	Systematic exposition - lecture. Examples.	6 hours
Elastic scattering of X-rays and thermal neutrons. Structure factor. Ewald's sphere. Structure of X-ray diffraction pattern	Systematic exposition - lecture. Examples.	8 hours
Real crystals: size effects, structural disorder and temperature effects	Systematic exposition - lecture. Examples.	4 hours
Optical transitions în semiconductors and semiconductor nanostructures. Optical density of states. Critical points. Excitons. Photoluminescence.	Systematic exposition - lecture. Examples.	8 hours

References:

19. P.Y. Yu, M. Cardona, *Fundamentals of semiconductors – physics and materials properties* (Springer, Berlin, Germany, 2005), 3-rd ed.
20. M. Fox, *Optical properties of solids* (Oxford University Press, Oxford, UK, 2001).
21. C. Giacovazzo (ed.), *Fundamentals of Crystallography* (Oxford University Press, Oxford, UK, 2002), 2-nd. ed..
22. Y. Waseda, E. Matsubara, K. Shinoda, *X-ray Diffraction Crystallography* (Springer Verlag, Berlin, Germany, 2011)
23. L. Ion, Lecture notes

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations

	Exposition. Guided work	
Bibliography: 10.		
8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Symmetry of crystalline structures. Point group. Space group.	Guided practical work	4 hours
X-ray diffraction. Determination of interplanar distances and of lattice constants. Identification of crystalline phases.	Guided practical work	4 hours
X-ray diffraction. Quantitative analysis. Williamson Hall plot. Rietveld method.	Guided practical work	4 hours
Ultrathin films. Grazing incidence X-ray diffraction.	Guided practical work	4 hours
X-ray reflectometry. Quantitative determinations (surface rugosity, thickness).	Guided practical work	4 hours
Optical transitions în direct band semiconductors. Optical properties.	Guided practical work	4 hours
Optical properties of ultrathin films	Guided practical work	4 hours
Bibliografie: 1. L. Ion, *Tehnici de investigare structurală şi morfologică bazate pe împrăştierea razelor X* (îndrumător de laborator) 2. P.Y. Yu, M. Cardona, *Fundamentals of semiconductors – physics and materials properties* (Springer, Berlin, Germany, 2005), 3-rd ed.		
8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this course is similar to that of other courses taught at Romanian and foreign universities, and is designed such that the student develops abilities of investigating the crystalline structure and the interactions of solid materials with the electromagnetic field, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Ability to exemplify	Written exam Homework	50% 25%
10.5.1. Tutorials			
10.5.2. Practicals	- Use of structure investigation techniques- - Ability to analyse experimental data	Lab reports	25%
10.5.3. Project [if applicable]			

10.6. Minimal requirements for passing the exam
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.108 Magnetism. Spintronics.

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title		**Magnetism. Spintronics**						
2.2. Teacher			Conf. dr. George Alexandru NEMNES					
2.3. Tutorials instructor(s)			Conf. dr. George Alexandru NEMNES					
2.4. Practicals instructor(s)								
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	20
3.2.2. Research in library, study of electronic resources, field research	20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	25
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Solid State I, Thermodynamics and statistical physics, Physical Electronics, Equations of mathematical physics
4.2. competences	11. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	-

6. Acquired specific competencies

Professional competencies	**32.** Identification and adequate use of physics laws in a given context; identification and adequate use of notions and specific physics laws for magnetic materials. **33.** Solving physics problems in given conditions. **34.** Creative use of acquired physical knowledge to understand and to construct models for physical processes and properties of magnetic materials and spintronic devices. **35.** Analysis and communication of scientific data, communication for physics popularization. **36.** Use and development of specific software tools.
Transversal competencies	**37.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **38.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Investigation of magnetic properties of materials and spin transport in electronic devices.
7.2. Specific objectives	- Understanding the origin of the magnetism from fundamental perspective. - Indepth understanding of magnetic interactions. - Analysis of specific spin and charge transport models. - The capacity to analyze and interpret experimental data and formulate rigorous theoretical conclusions. - The capacity to employ mathematical and numerical models for modelling the physical phenomena.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introduction. Magnetic materials. Magnetic suceptibility. Types of magnetism.	Systematic exposition - lecture. Examples.	2 hours
Langevin paramagnetism. Pauli paramagnetism.	Systematic exposition - lecture. Examples.	2 hours
Langevin diamagnetism. Landaau levels. Pauli diamagnetism for free electrons.	Systematic exposition - lecture. Examples.	4 hours
Ferromagnetism. Curie-Weiss law. Stoner criterion.	Systematic exposition - lecture. Examples.	2 hours
Exchange integral. Super-exchange and double-exchange interaction. RKKY interaction.	Systematic exposition - lecture. Examples.	4 hours
Spin glasses. Dynamical properties. Phase transitions.	Systematic exposition - lecture. Examples.	4 hours
Giant magnetoresistance. Rashba and Dresselhaus spin-orbit interaction. Datta-Das field effect transistor.	Systematic exposition - lecture. Examples.	4 hours
Spin relaxation mechanisms. Spin scattering on magnetic impurities. Spin filters.	Systematic exposition - lecture. Examples	4 hours
Magnetic domains. FORC diagrams.	Systematic exposition -	2 hours

	lecture. Examples	

References:

24. R.M. White, *Quantum Theory of Magnetism* (Springer, Berlin, 1983).
25. R.M. Martin, Electronic Structure: Basic Theory and Practical Methods (Cambridge University Press, Cambridge, UK, 2004)
26. P. Mohn, *Magnetism in the solid state* (Springer, Berlin, 2002)
    Teruya Shinjo, *Nanomagnetism and Spintronics* (Elsevier, Amsterdam, 2009)
27. I. Munteanu, *Fizica solidului* (Editura Universității din București, 2003)

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Paramagnetic materials. Applications.	Exposition. Guided work	4 ore
Diamagnetic materials. Applications.	Exposition. Guided work	4 ore
Exchange interaction. Applications of Hartree-Fock approximation.	Exposition. Guided work	4 ore
Ising spin models. Ferromagnets, antiferromagnets and spin glasses.	Exposition. Guided work	4 ore
Spin scattering in graphene nanoribbons.	Exposition. Guided work	4 ore
Charge and spin transport in magnetic quantum wires. Introduction to *ab initio* models.	Exposition. Guided work	4 ore
FORC diagrams. Identification of magnetic domain structures.	Exposition. Guided work	4 ore

Bibliography:

R.M. Martin, Electronic Structure: Basic Theory and Practical Methods (Cambridge University Press, Cambridge, UK, 2004)
P. Mohn, *Magnetism in the solid state* (Springer, Berlin, 2002)
Teruya Shinjo, *Nanomagnetism and Spintronics* (Elsevier, Amsterdam, 2009)

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	4 ore

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

Bibliography:

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements;	Written and oral exam	50%

	- Correct use of physical models and of specific mathematical methods; - Ability to analyse specific examples;		
10.5.1. Tutorials	- Use of specific physical and mathematical methods and techniques;	Homework, research projects	50%
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	xx%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solutions to indicated subjects (for mark 5) in final exam			

Date

10.06.2019

Teacher's name and signature

Conf. dr. George Alexandru Nemnes

Practicals/Tutorials instructor(s) name(s) and signature(s)

Conf. dr. George Alexandru Nemnes

Date of approval

10.06.2019

Head of department,

Conf. dr. Petrică Cristea

DI.109 Organic semiconductors and Applications

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Organic semiconductors and applications**								
2.2. Teacher	Lect. dr. Sorina Iftimie								
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)	Lect. dr. Sorina Iftimie, Prof. dr. Ştefan Antohe								
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	30
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum Mechanics, Solid State Physics 1, Electricity and Magnetism, Electrodynamics
4.2. competences	12. Understanding peculiarities of electron states in organic semiconductors 13. Knowledge and understanding of peculiarities of transport and optical phenomena in organic semiconductors 14. Understanding underlying physical phenomena 15. Ability to analyze and understand relevant experimental data and to formulate rigorous conclusions

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, video-projector, internet connection)
5.2. for tutorials/practical classes	Experimental set-ups in Thin Films Laboratory and Nanotechnology Laboratory of Materials and Devices for Electronics and Optoelectronics R&D Center

6. Acquired specific competencies

Professional competencies	**39.** Identification and adequate use of physics laws in a given context; identification and adequate use of notions and specific physics laws for organic semiconductors. **40.** Solving physics problems in given conditions. **41.** Creative use of acquired physical knowledge to understand and to construct models for physical processes and properties of organic semiconductors. **42.** Analysis and communication of scientific data. **43.** Use and development of specific laboratory equipments.
Transversal competencies	**44.** Efficient use of scientific information resources for professional formation in English. **45.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and development of organic semiconductors by physical and chemical methods for electronic and optoelectronic applications
7.2. Specific objectives	Introduction to small molecules organic semiconductors, aromatic hydrocarbon, organic dyes, donor-acceptor complexes, and semiconducting polymers Study of intermolecular interactions in organic solids Molecular orbitals, molecular excited states, band structure of molecular crystals Excitons in organic solids, Mott-Wannier excitons, Frenkel excitons, Le Blanc's model, Katz-Rice-Chois-Jortner model Transport mechanism in organic solids, anisotropy of conductivity Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Structural properties of organic semiconductors: correlation between chemical structure and semiconducting properties	Systematic exposition - lecture. Examples.	4 hours
Crystalline structure of organic semiconductors: structure of small molecular weight organic solids, structure of large molecular weight solids, point-like defects, diffusion in organic solids, diffusion mechanisms, methods to determine the diffusion coefficient, doping of organic semiconductors	Systematic exposition - lecture. Examples.	4 hours
Electron structure of organic solids: intermolecular interactions in organic solids	Systematic exposition - lecture. Examples.	4 hours
Le Blanc's model, Katz-Rice-Chois-Jortner model	Systematic exposition - lecture. Examples.	2 hours
Energy transfer in organic solids	Systematic exposition - lecture. Examples.	2 hours
Excitons: Mott-Wannier excitons, Frenkel excitons.	Systematic exposition - lecture. Examples.	2 hours

Exciton diffusion, exciton triplets, influence of lattice defects on exciton diffusion.	Systematic exposition - lecture. Examples.	2 hours
Polarons in molecular crystals.	Systematic exposition - lecture. Examples.	2 hours
Charge transport in organic solids: transport mechanisms in organic solids – tunnel effect, hopping mechanism	Systematic exposition - lecture. Examples.	2 hours
Charge transport in organic solids: transport mechanisms in organic solids – band transport mechanism, activation energy, anisotropy of conductivity, influence of pressure on dark conductivity of organic solids	Systematic exposition - lecture. Examples.	2 hours
Resume of lecture	Systematic exposition - lecture. Examples.	2 hours

References:

28. ***S. Antohe**, Materiale și Dispozitive Electronice Organice (Editura. Universității din București, București, 1996)*
29. S. Antohe, *Electronic and Optoelectronic Devices Based on Organic Thin Films,* in *Handbook of Organic Electronics and Photonics: Electronic Materials and Devices*, H. Singh-Nalwa (Ed.) (American Scientific Publishers, Los Angeles, California, USA, 2006).
30. S. Antohe, S. Iftimie, L. Hrostea, V.A. Antohe, M. Girtan, *A critical review of photovoltaic cells based on organic monomeric and polymeric thin film heterojunctions* in *Thin Solid Films* 642, 219-231, 2017.
31. N.F. Mott, E.A. Davis, *Electron processes in non-crystalline materials* (Clarendon Press, Oxford, 1979).
32. W. Helfrich, *Physics and Chemistry of the Organic Solid State* (Wiley Interscience, New York, 1967).
33. Lecture notes available on http://solid.fizica.unibuc.ro.

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Preparation methods for organic thin films	Guided practical work	4 hours
Methods to determine the thickness of organic thin films	Guided practical work	2 hours
Structural characterization of organic semiconductors	Guided practical work	4 hours
Surface topography investigations of organic semiconductors by atomic force microscopy (AFM)	Guided practical work	4 hours
Morphological analysis of organic semiconductors by scanning electron microscopy (SEM)	Guided practical work	4 hours
Electrical behavior of organic semiconductors	Guided practical work	4 hours
Optical characterization of organic semiconductors	Guided practical work	4 hours
Hand-on lab test & quiz	Group project	2 hours

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

References:

1. ***S. Antohe***, *L. Ion, F. Stanculescu, S. Iftimie, A. Radu and V. A. Antohe, "Fizica si tehnologia materialelor semiconductoare – Lucrari practice", Ars Docendi, Universitatea din Bucuresti, 165 pages, 2016, ISBN: 978-973-558-940-0* ***2.***

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyze specific examples;	Written exam	70%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	30%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher(s) name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Lect. dr. Sorina Iftimie	Lect. dr. Sorina Iftimie Prof. dr. Ştefan Antohe

Date of approval
10.06.2019

Head of department,
Assoc. Prof. dr. Petrică Cristea

DI.110 Preparation methods for nanomaterials

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title		**Preparation methods for nanomaterials**							
2.2. Teacher			Lect. dr. Sorina Iftimie						
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)			Lect. dr. Sorina Iftimie, Assoc. Prof. Vlad-Andrei Antohe						
2.5. Year of study	1	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**	
							Type[2]		

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	20
3.2.2. Research in library, study of electronic resources, field research	20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	25
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Thermodynamics, Solid State Physics I, Optics
4.2. competences	16. Knowledge of modern technologies for producing nanomaterials and nanostructures 17. Understanding underlying physical phenomena 18. Ability to analyze and understand relevant experimental data and to formulate rigorous conclusions

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, video-projector, internet connection)
5.2. for tutorials/practical	**3.** Experimental set-ups in Thin Films Laboratory and Nanotechnology

classes	Laboratory of Materials and Devices for Electronics and Optoelectronics R&D Center

6. Acquired specific competencies

Professional competencies	**46.** Identification and adequate use of physics laws in a given context; identification and adequate use of notions and specific physics laws for nanostructures. **47.** Solving physics problems in given conditions. **48.** Creative use of acquired physical knowledge to understand and to construct models for physical processes and properties of nanostructures. **49.** Analysis and communication of scientific data. **50.** Use and development of specific laboratory equipments.
Transversal competencies	**51.** Efficient use of scientific information resources for professional formation in English. **52.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and development of nanostructures by physical and chemical methods for electronic and optoelectronic applications.
7.2. Specific objectives	Studies of thermodynamically phenomena and processes of development of thin films Study of dc/rf magnetron sputtering Study of thermal evaporation Study of pulsed laser deposition Study of electrochemical deposition Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Nanomaterials: relevant length scales. Specific physical properties.	Systematic exposition - lecture. Examples.	2 hours
Crystal growth models. Thermodynamic and kinetics of crystal growth.	Systematic exposition - lecture. Examples.	2 hours
Fabrication techniques. Physical principles. dc and rf magnetron sputtering thermal evaporation pulsed laser deposition electrochemical deposition spin-coating	Systematic exposition - lecture. Examples.	4 hours
Self-assembled materials at nanoscale	Systematic exposition - lecture. Examples.	2 hours
Applications to electronics and optoelectronics	Systematic exposition - lecture. Examples.	4 hours
Applications to photovoltaic devices	Systematic exposition - lecture. Examples.	2 hours
Types of nanostructures	Systematic exposition - lecture. Examples.	2 hours
Top-down fabrication techniques. Lithography.	Systematic exposition - lecture. Examples.	2 hours
Bottom-up fabrication techniques; self-assembling at	Systematic exposition -	2 hours

nanoscale	lecture. Examples.	
Production of metallic and semiconductor nanowires by template based methods	Systematic exposition - lecture. Examples.	2 hours
Nanowires and nanotubes. Applications.	Systematic exposition - lecture. Examples.	2 hours
Resume of lecture	Systematic exposition - lecture. Examples.	2 hours

References:

34. T. Ohji, A. Wereszczak (Eds.), *Nanostructured materials and Nanotechnology* (Wiley, New York, 2009).

35. C. Dups, P. Houdy, and M. Lahmani, *Nanoscience. Nanotechnologies and Nanophysics* (Springer Verlag, Berlin, 2004).

36. M. Adachi, D.J. Lockwood (Eds.), *Self-organized nanoscale materials* (Springer Verlag, Berlin, 2006).

37. M. Kohler, W. Fritzsche, *Nanotechnology. An Introduction to Nanostructuring Techniques* (Wiley, New York, 2007).

38. Lecture notes available on http://solid.fizica.unibuc.ro

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Development of nanomaterials by dc magnetron sputtering	Guided practical work	4 hours
Development of nanomaterials by rf magnetron sputtering	Guided practical work	4 hours
Development of thin films by thermal vacuum evaporation	Guided practical work	4 hours
Fabrication of nanomaterials by pulsed laser deposition	Guided practical work	4 hours
Fabrication of nanostructures by electrochemical deposition	Guided practical work	4 hours
Fabrication of thin films by spin-coating	Guided practical work	2 hours
Hand-on lab test & quiz	Group project	2 hours

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

References:

1. Laboratory notes

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3.

			Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyze specific examples;	Written exam	70%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	30%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher(s) name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Lect. dr. Sorina Iftimie	Lect. dr. Sorina Iftimie Assoc. Prof. Vlad-Andrei Antohe

Date of approval
10.06.2019

Head of department,
Assoc. Prof. dr. Petrică Cristea

DI.112 Research activity

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title		**Research activity**							
2.2. Teacher									
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)		Prof. dr. Lucian Ion							
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**	
							Type[2]	**DI**	

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	0	Tutorials/Practicals	0/4
3.2. Total hours per semester	56	distribution: lecture	0	Tutorials/Practicals	0/56

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	0
3.2.2. Research in library, study of electronic resources, field research	5
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	10
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	15
3.4. Total hours per semester	75
3.5. ECTS	3

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics, Electrodynamics, Thermodynamics and statistical physics
4.2. competences	Using of specialized software for scientific data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	Research infrastructure (în research centers) for preparation and characterization of materials and nanostructures

6. Acquired specific competencies

Professional competencies	**53.** Creative use of acquired knowledge for preparation and characterization of materials and nanostructures **54.** Solving physics problems in given conditions **55.** Analysis and communication of scientific data, communication for physics popularisation. **56.** Use of professional software
Transversal competencies	**57.** Efficient use of scientific information and communication resources for professional formation in English. **58.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and use of experimental or theoretical methods used în fabrication and/or characterization of materials and nanostructures
7.2. Specific objectives	Highlighting of specific problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
	Systematic exposition - lecture. Examples.	
References: **39.**		
8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
	Exposition. Guided work	
Bibliography: 19.		
8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	
Bibliografie: 1.		
8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Experimental methods used in fabrication and/or characterization of materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student
Theoretical models for description of physical properties/physical phenomena related to materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student

Bibliography:
- to be indicated by the coordinator of the research activity

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this discipline unit is related to research themes proposed to students and is designed such that the student develops abilities of investigating the physical properties of materials and nanostructures, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture			
10.5.1. Tutorials			
10.5.2. Practicals			
10.5.3. Project [if applicable]	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Knowledge of experimental techniques - Ability to analyse scientific data	Research report	100%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Final mark reflects the assessment of the coordinator of the research activity and is related to the knowledge level of experimental/theoretical models used and to the correct interpretation of scientific data.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.203 Nanostructures for electronics and optoelectronics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Nanostructures for electronics and optoelectronics**							
2.2. Teacher	Assoc. Prof. Ph.D. Eng. Vlad-Andrei ANTOHE							
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)	Assoc. Prof. Ph.D. Eng. Vlad-Andrei ANTOHE Assist. Prof. Ph.D. Sorina IFTIMIE							
2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	**DI**

[1] deepening (DA), specialty/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	0/2
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	0/28

Distribution of estimated time for study	Hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	15
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	20
3.2.4. Examination	4
3.2.5. Other activities	0

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Introduction in Nanotechnology, Preparation and characterization methods at nanoscale, Solid State Physics, Materials Science, Optics, Electricity, Electronics
4.2. competences	20. Skills in handling small-scale lab equipment and basic research tools to perform complex scientific experiments 21. Using of software tools for data analysis and processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, video-projector, internet connection)
5.2. for tutorials/practicals	MDEO research infrastructure and Nanotechnology lab.

6. Acquired specific competencies

Professional competencies	**59.** Understanding of physico-chemical processes involved in the fabrication of nanostructures and nanomaterials **60.** Knowledge of using modern micro- and nanotechnology to design various types of nanostructured devices **61.** Skills in handling electrochemical equipment for the preparation of quasi-1D nanostructures (i.e. nanowires, nanotubes, nanorods, etc.) **62.** Abilities in experimental data analysis and interpretation in order to formulate relevant and rigorous conclusions **63.** Competences of employing advanced characterization tools of nanomaterials and of specific nanostructured opto-/electronic devices
Transversal competencies	**64.** Efficient use of the available scientific information resources (specialized books, research papers, internet search) **65.** Responsible implementation of professional tasks while carefully taking into account the ethics and deontology **66.** Ability to communicate in English the scientific results to a broad audience in a rigorous and clearly structured manner

7. Course objectives

7.1. General objective	Development and characterization of novel nanostructured materials, to be used as active functional building blocks within modern electronic and optoelectronic devices
7.2. Specific objectives	Preparation methods of nanostructures and nanomaterials Advanced characterization of functional nanostructures Construction of sensors and biosensors based on nanostructured materials Fabrication of photovoltaic structures based on nanostructured materials

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introduction in nanoscale science and technology 1. Nanostructures. Types and classification 2. Nanometer-scale effects 3. Cleanrooms. Construction and classes	Systematic exposition - Lecture. Examples.	4 hours
Nanoporous templates in nanotechnology **4.** General considerations **5.** Supported alumina templates **6.** Template-assisted electrochemical synthesis	Systematic exposition - Lecture. Examples.	4 hours
Lithography patterning approaches **2.** General considerations **3.** Optical lithography **4.** Electron-beam lithography	Systematic exposition - Lecture. Examples.	4 hours
Nanostructures growth and spatial nanolocalization 1. Top down and bottom-up approaches 2. Localization with single-nanowire resolution 3. Types of nanostructured devices	Systematic exposition - Lecture. Examples.	4 hours
Introduction in nanostructured sensing and biosensing 1. Sensors and biosensors. Generalities 2. Nanostructured capacitive sensors 3. Nanostructured chemiresistive sensors	Systematic exposition - Lecture. Examples.	6 hours
Introduction in Photovoltaics 1. Solar cells. General considerations 2. Main performance quantifiers 3. Solar cells based on A^2-B^6 heterojunctions	Systematic exposition - Lecture. Examples.	6 hours

References: **40.** V. A. Antohe, "Capacitive Sensors Based on Localized Nanowire Arrays. Nanotechnology & Device Integration Routes", Lambert Academic Publishing (LAP), 2013, ISBN: 978-3-659-38899-6 1. M. Di Ventra, S. Evoy, J. R. Heflin Jr., Kluwer, "Introduction to Nanoscale Science and Technology", Academic Publishers 2004, ISBN: 1-402-07757-2 1. B. Bhushan, "Springer Handbook of Nanotechnology", Springer 2007, ISBN: 3-540-29855-X 2. V. A. Antohe, Lecture notes		
8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Anodic oxidation of thin aluminum films.	Exposition. Guided practical work	4 hours
Electrochemical deposition within supported nanoporous alumina templates	Exposition. Guided practical work	4 hours
Synthesis of electro-conductive polymers for sensing and biosensing	Exposition. Guided practical work	4 hours
Nanowires and nanotubes. Scanning electron microscopy (SEM)	Exposition. Guided practical work	4 hours
Electron-beam lithography (EBL)	Exposition. Guided practical work	4 hours
Topography of thin films. Atomic force microscopy (AFM)	Exposition. Guided practical work	4 hours
Nanolithography with an atomic force microscope (AFM)	Exposition. Guided practical work	4 hours
Bibliography: S. Antohe, L. Ion, F. Stanculescu, S. Iftimie, A. Radu and V. A. Antohe, "Fizica si tehnologia materialelor semiconductoare – Lucrari practice", Ars Docendi, Universitatea din Bucuresti, 165 pages, 2016, ISBN: 978-973-558-940-0 S. Matéfi-Tempfli, M. Matéfi-Tempfli, A. Vlad, V. A. Antohe and L. Piraux, "Nanowires and nanostructures fabrication using template methods: a step forward to real devices combining electrochemical synthesis with lithographic techniques", J. Mater. Sci – Mat. Electron. 20(1), 249-254 (2009), doi: 10.1007/s10854-008-9568-6		
8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Presentation of a scientific paper	Exposition. Individual work	4 hours
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics, as well as of nanoscale science and technology. The contents and teaching methods were selected after a thorough analysis of similar course units within universities from Romania and European Union (Hannover University – Germany and Catholique University of Louvain – Belgium). The entire content of this lecture is thoroughly in line with the requirements of the main employers from industry, research institutes, universities or high-schools.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements	Written and oral exam	25%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Ability to use various top-down and bottom-up methods to design nanostructured devices	Colloquium	50%
10.5.3. Project [if applicable]	- Presentation of a scientific paper - Quality of the presentation - Ability to communicate the scientific results in a clear and structured manner - Ability to address the questions and comments arising during and after the presentation	Oral presentation with Q&A session	25%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Attending the presentations session and presenting a scientific paper, as a partial assessment. Finalizing the work associated with the practical sessions and obtaining a mark of 5 at the colloquium. Correctly addressing the final exam topics for a minimal mark of 5.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
20.05.2019	Assoc. Prof. Ph.D. Eng. Vlad-Andrei ANTOHE	Assoc. Prof. Ph.D. Eng. Vlad-Andrei ANTOHE
		Assist. Prof. Ph.D. Sorina IFTIMIE

Date of approval
10.06.2019

Head of department,
Conf. univ. dr. Petrică CRISTEA

DI.205 Research activity

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Research activity**								
2.2. Teacher									
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)	Prof. dr. Lucian Ion								
2.5. Year of study	2	2.6. Semester	3	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	6	distribution: lecture	0	Tutorials/Practicals	0/6
3.2. Total hours per semester	84	distribution: lecture	0	Tutorials/Practicals	0/84

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	0
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	32
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	62
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics, Electrodynamics, Thermodynamics and statistical physics
4.2. competences	Using of specialized software for scientific data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	Research infrastructure (în research centers) for preparation and characterization of materials and nanostructures

6. Acquired specific competencies

Professional competencies	**67.** Creative use of acquired knowledge for preparation and characterization of materials and nanostructures **68.** Solving physics problems in given conditions **69.** Analysis and communication of scientific data, communication for physics popularisation. **70.** Use of professional software
Transversal competencies	**71.** Efficient use of scientific information and communication resources for professional formation in English. **72.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and use of experimental or theoretical methods used în fabrication and/or characterization of materials and nanostructures
7.2. Specific objectives	Highlighting of specific problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
	Systematic exposition - lecture. Examples.	
References: **41.**		
8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
	Exposition. Guided work	
Bibliography: 22.		
8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	
Bibliografie: 1.		
8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Experimental methods used in fabrication and/or characterization of materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student
Theoretical models for description of physical properties/physical phenomena related to materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student

Bibliography:
- to be indicated by the coordinator of the research activity

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this discipline unit is related to research themes proposed to students and is designed such that the student develops abilities of investigating the physical properties of materials and nanostructures, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture			
10.5.1. Tutorials			
10.5.2. Practicals			
10.5.3. Project [if applicable]	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Knowledge of experimental techniques - Ability to analyse scientific data	Research report	100%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Final mark reflects the assessment of the coordinator of the research activity and is related to the knowledge level of experimental/theoretical models used and to the correct interpretation of scientific data.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.206 Physics of liquid crystals and polymeric materials. Applications.

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Physics of liquid crystals and polymeric materials. Applications.**							
2.2. Teacher	Prof. dr. Valentin Barna							
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)	Prof. dr. Valentin Barna							
2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DA**
							Type[2)]	**DI**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	0/2
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	0/28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	21
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	30
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	81
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Numerical methods, Molecular physics and heat, Thermodynamics and Statistical Physics
4.2. competences	23. Knowledge and understanding of physical properties of liquid crystals 24. Knowledge and understanding of physical properties of polymeric materials 25. Knowledge and understanding of the physical processes and phenomena typical for liquid crystals and polymeric materials based devices 26. Understanding underlying physical phenomena 27. Ability to analyze and understand relevant experimental data and to formulate rigorous conclusions

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, video-projector, internet connection)
5.2. for tutorials/practical classes	Experimental set-ups in Thin Films Laboratory and Nanotechnology Laboratory of Materials and Devices for Electronics and Optoelectronics R&D Center

6. Acquired specific competencies

Professional competencies	**73.** Knowledge and explanation of the physical properties of liquid crystals and polymeric materials **74.** Knowledge and explanation of the physical properties of liquid crystals and polymeric materials based devices **75.** Development of specific capacities of analysis using fundamental processes and phenomena in physics **76.** Development of the ability to create and properly use of mathematical and numerical models applied to liquid crystals and polymeric materials and their applications **77.** Analysis and communication of scientific data. **78.** Use and development of specific laboratory equipments.
Transversal competencies	**79.** Efficient use of scientific information resources for professional formation in English. **80.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and understanding of the physical properties of liquid crystals and polymeric materials and their applications
7.2. Specific objectives	Liquid crystals: physical properties, chemical properties, chemical structure, growth methods Nematic liquid crystals: phase transitions Continuum theory applied to liquid crystals Liquid crystals displays: physical properties, chemical properties, growth methods Liquid crustal-impurities compounds Polymer liquid crystals: physical properties, chemical properties, growth methods Structure-properties relation for polymer liquid crystals Supramolecular polymers Liquid crystals and polymer liquid crystals based devices

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Physics of liquid crystals – classification, physical and chemical properties, aggregation states	Systematic exposition - lecture.	2 hours
Nematic liquid crystals: phase transitions, density functional theory, nematic liquid crystals – isotropic materials interface	Systematic exposition - lecture.	4 hours
Continuum theory applied to liquid crystals: Freank-Oseen free energy, physical phenomena at surface, Fredericks effect for various configurations.	Systematic exposition - lecture. Examples.	4 hours
Liquid crystals displays: definition, classification, physical properties	Systematic exposition - lecture. Examples.	2 hours
Liquid crustal-impurities compounds	Systematic exposition -	2 hours

	lecture. Examples.	
Polymer liquid crystals: classification, physical and chemical properties, growth methods	Systematic exposition - lecture. Examples.	2 hours
Structure-properties relation for polymer liquid crystals: geometric stereoisomers, optical stereoisomers, stereoisomerism to polymers	Systematic exposition - lecture. Examples.	2 hours
Supramolecular polymers: physical properties, chemical properties	Systematic exposition - lecture. Examples.	4 hours
Liquid crystals and polymer liquid crystals based devices	Systematic exposition - lecture. Examples.	4 hours
Resume of lectures.	Systematic exposition - lecture. Examples.	2 hours

References:

42. L. Georgescu, V. Popa-Niţă, E. Barna, C. Berlic, *Fizica cristalelor lichide*, Ed. Universităţii din Bucureşti, 2002

43. P.G. de Gennes, J. Prost, *The physics of liquid crystals*, Oxford University Press, 1993

44. S. Chandrasekhar, *Liquid crystals*, Cambridge University Press, 1994

45. C. Moţoc, G. Iacobescu, *Cristale lichide – proprietăţi fizice şi aplicaţii*, Editura Universităţii din Craiova, 2004

46. L. Constantinescu, C. Berlic, *Structura polimerilor. Metode de studiu*, Editura Universităţii din Bucureşti, 2003

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Building of liquid crystal cell with various configurations and by different methods	Guided practical work	4 hours
Aligned nematic liquid crystal cell	Guided practical work	2 hours
Twisted nematic liquid crystal cell	Guided practical work	2 hours
Electro-optical characterization of a liquid crystal cell and polymeric thin film	Guided practical work	2 hours
Liquid crystal cell: molecular alignment at surface. Homeotropic alignment. Planar alignment	Guided practical work	2 hours
Polymerization process by cold plasmas. Atomic force microscopy analysis and optical microscopy investigations of obtained polymeric film. Evaluation of specific parameters	Guided practical work	4 hours
Liquid crystals displays: electro-optical characterization – pixels and optical filters	Guided practical work	4 hours
The anisotropy of output functions. Evaluation of Stokes parameters	Guided practical work	2 hours
Liquid-solid nucleation methods and phase transitions	Guided practical work	4 hours
Hand-on lab test & quiz	Group project	2 hours

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

References:

7. L. Georgescu, L. Constantinescu, E. Barna, C. Miron, C. Berlic, *Introducere în fizica polimerilor*, Editura Credis, Bucureşti, România, 2004 **8.** Shri Singh, *Liquid crystals. Fundamentals*, Editura World Scientific, 2002 **9.** L.M. Constantinescu, C. Berlic, V. Barna, *Fizico-chimia polimerilor. Aplicaţii*, Editura Universităţii din Bucureşti, 2006

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyze specific examples;	Written exam	70%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	30%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher(s) name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Valentin Barna	Prof. dr. Valentin Barna

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.208 Research activity

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Research activity**							
2.2. Teacher								
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)	Prof. dr. Lucian Ion							
2.5. Year of study	2	2.6. Semester	3	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	18	distribution: lecture	0	Tutorials/Practicals	0/18
3.2. Total hours per semester	180	distribution: lecture	0	Tutorials/Practicals	0/180

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	0
3.2.2. Research in library, study of electronic resources, field research	141
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	50
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	191
3.4. Total hours per semester	345
3.5. ECTS	15

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics, Electrodynamics, Thermodynamics and statistical physics
4.2. competences	Using of specialized software for scientific data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	Research infrastructure (în research centers) for preparation and characterization of materials and nanostructures

6. Acquired specific competencies

Professional competencies	**81.** Creative use of acquired knowledge for preparation and characterization of materials and nanostructures **82.** Solving physics problems in given conditions **83.** Analysis and communication of scientific data, communication for physics popularisation. **84.** Use of professional software
Transversal competencies	**85.** Efficient use of scientific information and communication resources for professional formation in English. **86.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and use of experimental or theoretical methods used în fabrication and/or characterization of materials and nanostructures
7.2. Specific objectives	Highlighting of specific problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
	Systematic exposition - lecture. Examples.	
References: **47.**		

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
	Exposition. Guided work	
Bibliography: 28.		

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	
Bibliografie: 1.		

8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Experimental methods used in fabrication and/or characterization of materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student
Theoretical models for description of physical properties/physical phenomena related to materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student

Bibliography:
- to be indicated by the coordinator of the research activity

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this discipline unit is related to research themes proposed to students and is designed such that the student develops abilities of investigating the physical properties of materials and nanostructures, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture			
10.5.1. Tutorials			
10.5.2. Practicals			
10.5.3. Project [if applicable]	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Knowledge of experimental techniques - Ability to analyse scientific data	Research report	100%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Final mark reflects the assessment of the coordinator of the research activity and is related to the knowledge level of experimental/theoretical models used and to the correct interpretation of scientific data.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DI.209 Finalization of master thesis

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Research activity**								
2.2. Teacher									
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)	Prof. dr. Lucian Ion								
2.5. Year of study	2	2.6. Semester	4	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**
							Type[2]	**DI**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	0	distribution: lecture	0	Tutorials/Practicals	0/0
3.2. Total hours per semester	0	distribution: lecture	0	Tutorials/Practicals	0/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	0
3.2.2. Research in library, study of electronic resources, field research	61
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	50
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	121
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics, Electrodynamics, Thermodynamics and statistical physics
4.2. competences	Using of specialized software for scientific data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	Research infrastructure (în research centers) for preparation and characterization of materials and nanostructures

6. Acquired specific competencies

Professional competencies	**87.** Creative use of acquired knowledge for preparation and characterization of materials and nanostructures **88.** Solving physics problems in given conditions **89.** Analysis and communication of scientific data, communication for physics popularisation. **90.** Use of professional software
Transversal competencies	**91.** Efficient use of scientific information and communication resources for professional formation in English. **92.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and use of experimental or theoretical methods used în fabrication and/or characterization of materials and nanostructures
7.2. Specific objectives	Highlighting of specific problems designed to understand the specific phenomena and to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
	Systematic exposition - lecture. Examples.	
References: **48.**		

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
	Exposition. Guided work	
Bibliography: 29.		

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	
Bibliografie: 1.		

8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Experimental methods used in fabrication and/or characterization of materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student
Theoretical models for description of physical properties/physical phenomena related to materials and nanostructures	Guided practical work	- specific types of activities, defined by the research theme chosen by student

Bibliography:
- to be indicated by the coordinator of the research activity

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this discipline unit is related to research themes proposed to students and is designed such that the student develops abilities of investigating the physical properties of materials and nanostructures, domains of interest for research institutes and companies with activities in Condensed Matter Physics, especially Nanotehnologies, as well as in education.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture			
10.5.1. Tutorials			
10.5.2. Practicals			
10.5.3. Project [if applicable]	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Knowledge of experimental techniques - Ability to analyse scientific data	Report on master thesis	100%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Final mark reflects the assessment of the coordinator of the research activity and is related to the knowledge level of experimental/theoretical models used and to the correct interpretation of scientific data.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

II. Elective course units

DO.111.1 Physics of mesoscopic systems

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Physics of mesoscopic systems**							
2.2. Teacher	Prof. dr. Lucian Ion							
2.3. Tutorials instructor(s)	Prof. dr. Lucian Ion							
2.4. Practicals instructor(s)								
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DO**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0
Distribution of estimated time for study					hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography					20
3.2.2. Research in library, study of electronic resources, field research					20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks					25
3.2.4. Examination					4
3.2.5. Other activities					

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics
4.2. competences	30. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	-

6. Acquired specific competencies

Professional competencies	**93.** Identificartion and adequate use of physics laws in a given context; identification and adequate use of notions and specific physics laws for mesoscopic systems. **94.** Solving physics problems in given conditions. **95.** Creative use of acquired physical knowledge to understand and to construct models for physical processes and properties of mesoscopic systems/nanostructures. **96.** Analysis and communication of scientific data, communication for physics popularisation. **97.** Use and development of specific software tools.
Transversal competencies	**98.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **99.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and analysis of the physical properties of mesoscopic systems
7.2. Specific objectives	Study of electronic structure, transport and optical properties of mesoscopic systems. Analysis of specific charge transport models. Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking în solving problems.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introduction: description of mesoscopic systems. Growth and processing methods. Length scales.	Systematic exposition - lecture. Examples.	4 hours
Electronic structure of mesoscopic systems. Envelope wavefunction method.	Systematic exposition - lecture. Examples.	4 hours
Anderson localization. Scaling theory of localization. Reduced dimensionality. Case $d \leq 2$. Case $d > 2$. Metal-insulator transition	Systematic exposition - lecture. Examples.	6 hours
Quantum interference effects în charge transport. Landauer-Büttiker formalism. Applications.	Systematic exposition - lecture. Examples.	4 hours
Chrage transport în magnetic fields. Shubnikov – de Haas oscillations. Integer quantum Hall effect.	Systematic exposition - lecture. Examples.	4 hours
Aharonov-Bohm effect. Berry phase.	Systematic exposition - lecture. Examples.	4 hours
Coulomb blockade în semiconductor nanostructures	Systematic exposition - lecture. Examples.	2 hours
References: **49.** D.K. Ferry, S.M. Goodnick, *Transport in nanostructures* (Cambridge University Press, Cambridge,		

UK, 1997).
50. P.A. Lee, T.V. Ramakrishnan, Rev. Mod. Phys. **57**, 287 (1985).
51. H. Bouchiat, Y. Gefen, S. Gueron, G. Montambaux, J. Dalibard (Eds.), *Nanophysics: Coherence and Transport* (Elsevier, Amsterdam, Netherland, 2005).
52. V.F. Gantmakher, *Electrons and disorder în solids* (Clarendon Press, Oxford, UK, 2005)
53. L. Ion, Course notes

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Electronic states în mesoscopic systems. Envelope wavefunction method. Aplications.	Exposition. Guided work	4 ore
Effect of disorder in 1D and 2D electronic systems.	Exposition. Guided work	4 ore
Electronic states in 2D electron systems in magnetic fields. Disorder effects.	Exposition. Guided work	4 ore
Charge transport în mesoscopic structures. R-matrix formalism.	Exposition. Guided work	4 ore
Charge transport in quantum wires. *Ab initio* models.	Exposition. Guided work	4 ore
Weak localization regime.	Exposition. Guided work	4 ore
Electron-phonon interaction în low-dimensional systems. Peierls transition.	Exposition. Guided work	4 ore

Bibliography:

L. Mihaly, M.C. Martin, *Solid State Physics – Problems and solutions* (Wiley, New York, USA, 1996)
S. Datta, *Electronic Transport în Mesoscopic Systems* (Cambridge University Press, Cambridge, UK, 1997).
Y. Imry, *Introduction to Mesoscopic Physics* (Oxford University Press, Oxford, UK, 1997)

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	4 ore

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

Bibliography:

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models	Written and oral exam	50%

	and of specific mathematical methods; - Ability to analyse specific examples;		
10.5.1. Tutorials	- Use of specific physical and mathematical methods and techniques;	Homework, research projects	50%
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	xx%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DO.111.2 Transport phenomena in disordered materials

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Transport phenomena in disordered materials**							
2.2. Teacher	Prof. dr. Lucian Ion							
2.3. Tutorials instructor(s)	Prof. dr. Lucian Ion							
2.4. Practicals instructor(s)	Prof. dr. Lucian Ion							
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	**DO**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	1/1
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	14/14

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	20
3.2.2. Research in library, study of electronic resources, field research	20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	25
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics
4.2. competences	31. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	Research infrastructure în MDEO research center

6. Acquired specific competencies

Professional competencies	**100.** Knowledge of transport phenomena în disordered electron systems **101.** Solving physics problems in given conditions. **102.** Creative use of acquired physical knowledge to understand and to construct models for physical processes in disordered electron systems. **103.** Analysis and communication of scientific data, communication for physics popularisation. **104.** Use and development of specific software tools.
Transversal competencies	**105.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **106.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Analysis of charge transport în disordered electron systems
7.2. Specific objectives	Study of electronic structure în disordered materials. Analysis charge transport models în disordered materials. Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking în solving problems.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Localization of electronic states in solids: structure of isolated impurity states; Lifschitz model of localization; structure of impurity bands in lightly doped semiconductors; structure of impurity bands in heavily doped semiconductors.	Systematic exposition - lecture. Examples.	6 hours
Hopping transport mechanism: experimental facts; Miller-Abrahams model; percolation models; nearest-neighbours hopping transport mechanism; dependence on impurity density; activation energy; variable-range hopping mechanism (Mott).	Systematic exposition - lecture. Examples.	12 hours
Hopping in magnetic field: magnetorezistance, dependence on magnetic field; Hall effect	Systematic exposition - lecture. Examples.	8 hours
Super-ohmic effects	Systematic exposition - lecture. Examples.	2 hours

References:

54. B.I. Shklovskii, A.L.Efros, *Electronic properties of doped semiconductors* (Springer, Heidelberg, 1984).

55. N.F. Mott, E.A. Davis, *Electron processes in non-crystalline materials* (Clarendon Press, Oxford, 1979).

56. S. Antohe, *Fizica semiconductorilor organici* (Editura Universității din București, București, 1997).

57. V.F. Gantmakher, *Electrons and disorder în solids* (Clarendon Press, Oxford, UK, 2005).B.I. Shklovskii, A.L.Efros, *Electronic properties of doped semiconductors* (Springer, Heidelberg, 1984).

58. N.F. Mott, E.A. Davis, *Electron processes in non-crystalline materials* (Clarendon Press, Oxford, 1979).

59. S. Antohe, *Fizica semiconductorilor organici* (Editura Universității din București, București, 1997).
60. V.F. Gantmakher, *Electrons and disorder în solids* (Clarendon Press, Oxford, UK, 2005).

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Electronic states în disordered systems. Applications.	Exposition. Guided work	6 hours
Metal/semiconductor contact phenomena	Exposition. Guided work	4 hours
Coulomb gap. Shklovskii-Efros model.	Exposition. Guided work	4 hours

Bibliography:

L. Mihaly, M.C. Martin, *Solid State Physics – Problems and solutions* (Wiley, New York, USA, 1996)
N.F. Mott, E.A. Davis, *Electron processes in non-crystalline materials* (Clarendon Press, Oxford, 1979).

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Percolation. Structure of critical cluster. Numerical methods – lattice models.	Guided practical work	4 hours
Charge transport în policrystaline/amorphous semiconductor films	Guided practical work	4 hours
Hopping magnetoresistance.	Guided practical work	2 hours
Thermally stimulated currents	Guided practical work	4 hours

8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union. The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyse specific examples;	Written and oral exam	50%
10.5.1. Tutorials	- Use of specific physical and mathematical methods and techniques;	Homework	25%
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Scientific reports on practical activities	25%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			

Requirements for mark 5 (10 points scale) All practicals have to be performed. Correct solving of subjects indicated as required for obtaining mark 5 (final exam and homeworks).

Date	Teacher’s name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DO.111.3 Linear transport theory

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Linear transport theory**							
2.2. Teacher				Prof. dr. Lucian Ion				
2.3. Tutorials instructor(s)				Prof. dr. Lucian Ion				
2.4. Practicals instructor(s)								
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	**DO**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	20
3.2.2. Research in library, study of electronic resources, field research	20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	25
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics
4.2. competences	32. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	Computing infrastructure în MDEO research center

6. Acquired specific competencies

Professional competencies	**107.** Knowledge of linear transport theory (linear response functions, generalized susceptibility, fluctuation-dissipation theorem) **108.** Solving physics problems in given conditions. **109.** Creative use of acquired physical knowledge to understand and to construct models for physical processes in disordered electron systems. **110.** Analysis and communication of scientific data, communication for physics popularisation. **111.** Use and development of specific software tools.
Transversal competencies	**112.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **113.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Formulation of linear response theory
7.2. Specific objectives	Study of linear response function and generalized susceptibility. Application to physical phenomena Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking în solving problems.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introduction to non-equilibrium thermodynamics. Thermodynamic forces and fluxes.	Systematic exposition - lecture. Examples.	4 hours
Linear response. Onsager's relations. Applications.	Systematic exposition - lecture. Examples.	4 hours
Quantum theory of linear response. Response function. Correlation functions. Generalized susceptibility.	Systematic exposition - lecture. Examples.	6 hours
Kramers-Krönig relations. Dissipation phenomena. Relaxation phenomena.	Systematic exposition - lecture. Examples.	4 hours
Fluctuation-dissipation theorem	Systematic exposition - lecture. Examples.	4 hours
Quantum transport. Kubo formula. Kubo-Greenwood formula.	Systematic exposition - lecture. Examples.	6 hours

References:

61. R. Balescu, *Equilibrium and nonequilibrium statistical mechanics* (Wiley, New York, USA, 1975).
62. C. Jacoboni, *Theory of electron transport in semiconductors* (Springer, Berlin, 2010).
63. J. Rammer, *Quantum transport theory* (Perseus, Reading, USA, 1998).
64. L. Ion, Note de curs

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Electric conductivity in disordered electron systems.	Exposition. Guided work	4 ore
Susceptibility of electron gas. Aproximations.	Exposition. Guided work	4 ore
Dynamic structure factor	Exposition. Guided work	4 ore
Aplications: dielectric relaxation; magnetic resonance	Exposition. Guided work	8 ore

Aplications: light scattering on density fluctuations	Exposition. Guided work	4 ore
Aplications: fluctuation-dissipation theorem	Exposition. Guided work	4 ore
Bibliography:		
8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	
8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union. The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyse specific examples;	Written and oral exam	50%
10.5.1. Tutorials	- Use of specific physical and mathematical methods and techniques;	Homework	50%
10.5.2. Practicals			
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5 (final exam and homeworks).			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Lucian Ion	Prof. dr. Lucian Ion

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DO.201.1 Nonlinear Optics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Nonlinear Optics**								
2.2. Teacher	Prof. dr. Daniela Dragoman								
2.3. Tutorials instructor(s)	Prof. dr. Daniela Dragoman								
2.4. Practicals instructor(s)	Conf. Dr. Ciceron Berbecaru								
2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**
							Type[2]	**DO**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	1.43/0.57
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	20/8

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	20
3.2.2. Research in library, study of electronic resources, field research	20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	25
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	65
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics
4.2. competences	Computational physics abilities Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	Specifically equipped laboratory

6. Acquired specific competencies

Professional competencies	**1.** Identification and adequate use of the specific laws and concepts of nonlinear optics **2.** Solving physics problems in given conditions **3.** Creative use of acquired knowledge for understanding and modelling of nonlinear processes and for designing optical systems and experimental set-ups for their observation **4.** Analysis and communication of scientific data, communication for physics popularisation. **5.** Use and development of specific software tools
Transversal competencies	**6.** Efficient use of scientific information and communication resources for professional formation in English. **7.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and analysis of the specific physical processes in nonlinear optics and of the experimental conditions for their observation
7.2. Specific objectives	Study of parametric nonlinear optical phenomena in media with susceptibilities of the second and third order. Correct use of the coupled mode formalism Highlighting at each chapter the applications of the studied phenomena and of the required experimental set-ups in order to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introductive: Maxwell equations in dielectric media. Polarization mechanisms. Parametric nonlinear optical phenomena	Systematic exposition - lecture. Examples.	4 hours
Birefringent crystals. The refractive index ellipsoid. Light propagation in anisotropic media. Phase matching conditions	Systematic exposition - lecture. Examples.	4 hours
Second harmonic generation. The second order nonlinear polarization tensor	Systematic exposition - lecture. Examples.	2 hours
Coupled-mode formalism. Efficiency of second harmonic generation; designing an optical system for maximizing the efficiency	Systematic exposition - lecture. Examples.	3 hours
Coupled-mode formalism for three-wave mixing. Examples of sum- and difference-frequency generation, parametric oscillations	Systematic exposition - lecture. Examples.	3 hours
Linear and quadratic electro-optic effects. Symmetry of the polarization tensor. Polarization matrices. Aplications in electromagnetic field modulation	Systematic exposition - lecture. Examples.	4 hours
Coupled-mode formalism for four-wave mixing. Examples of third-harmonic generation, phase conjugation	Systematic exposition - lecture. Examples.	2 hours
Pulse propagation in nonlinear media. Propagation	Systematic exposition -	6 hours

regimes. Optical solitons	lecture. Examples.	

References:

1. R. Dabu, I. Gruia, A. Stratan, *Noţiuni fundamentale de optică neliniară şi lucrări de laborator*, Editura Univ. Bucuresti, 2005
2. B.E.A. Saleh, M.C. Teich, *Fundamental of Photonics*, 2nd edition, Wiley, 2007, Chapter 21: Nonlinear Optics
3. G. New, *Introduction to Nonlinear Optics*, Cambridge University Press, 2011
4. R. Boyd, *Nonlinear Optics*, 3rd edition, Academic Press, 2008
5. C. Manzoni, G. Cerullo, Design criteria for ultrafast optical parametric amplifiers, J. Opt. 18, 103501, 2016, acces liber
6. D. Dragoman, *Optoelectronica integrata*, Editura Univ. Bucuresti, 2003
7. D. Dragoman, Lecture notes

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Birefringence in uniaxial crystals. Phase matching in parametric nonlinear phenomena. Collinear and noncollinear configurations	Exposition. Guided work	4 hours
Symmetry properties of the susceptibility tensor Examples. Effective susceptibility	Exposition. Guided work	4 hours
Conversion efficiency in parametric nonlinear phenomena. Angular and spectral acceptances	Exposition. Guided work	2 hours
Symmetry properties of the electro-optic tensor. Examples. Induced birefringence	Exposition. Guided work	4 hours
Quantum theory of the nonlinear susceptibility. Nonlinear optics in the two-level approximation	Exposition. Guided work	6 hours

Bibliography:

33. R. Dabu, I. Gruia, A. Stratan, *Noţiuni fundamentale de optică neliniară şi lucrări de laborator*, Editura Univ. Bucuresti, 2005
34. R. Boyd, *Nonlinear Optics*, 3rd edition, Academic Press, 2008
35. G. New, *Introduction to Nonlinear Optics*, Cambridge University Press, 2011
36. D. Dragoman, Problem set

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Electro-optic effect	Guided practical work	4 hours
Pyro-electric effect	Guided practical work	4 hours

Bibliography:

A. Yariv, *Quantum Electronics*, Ed. John-Wiley and Sons, 1989
O.G. Vlokh, On the dispersion of the electro–optic coefficient in ADP and KDP crystals, Kristallografiya **7**, 632–633, 1962
S.B. Lang, Pyroelectricity: From ancient curiosity to modern imaging tool, Phys. Today 58, 31, 2005
J.I. Sirotin, M.P. Saskolskaia, *Fizica Cristalelor*, Ed. Enciclopedică, Bucureşti, 1981

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

Bibliography:

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this course is designed to lead to the formation of instrumental-application specific competences (such as the design of optical systems for special applications; the use of models and simulation methods, as well as generating and investigation techniques, of electromagnetic fields with relevant

characteristics for certain applications), of interest for research institutes in Laser Physics and/or Physics of Materials and education. Because of the importance of the course for modern applications of high-power lasers, the content and the teaching methods have been put into correspondence with similar courses taught at other universities (Univ. Friedrich Schiller Jena, Germany, Institute of Optics, Univ. of Rochester, USA, Institut d'Optique, Palaiseau, France) as well as with the experimental facilities of the research institutes on the Măgurele platform

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Ability to exemplify	Written exam	50%
10.5.1. Tutorials	- Use of specific physical and mathematical methods for solving a given problem;	Written exam	25%
10.5.2. Practicals	- Use and correct application of experimental techniques; - Data interpretation	Exam	25%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5 at the written exam Attendance of all practicals and mark 5 at colloquim			

Date	Teacher's name and signature	Tutorials/Practicals instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Daniela Dragoman	Prof. dr. Daniela Dragoman Conf. dr. Ciceron Berbecaru

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DO.201.2 Physics of dielectric materials

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Physics of dielectric materials**
2.2. Teacher	Conf. Dr. Ciceron Berbecaru
2.3. Tutorials instructor(s)	
2.4. Practicals instructor(s)	Conf. Dr. Ciceron Berbecaru

2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DO**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	0/2
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	0/28

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	30
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Thermodynamics and statistical physics
4.2. competences	Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	Specifically equipped laboratory

6. Acquired specific competencies

Professional competencies	**8.** Identification and adequate use of the specific laws and concepts of dielectric materials physics **9.** Solving physics problems in given conditions **10.** Creative use of acquired knowledge for understanding and modelling of physical phenomena associated to dielectrics **11.** Analysis and communication of scientific data, communication for physics popularisation. **12.** Use and development of specific software tools
Transversal competencies	**13.** Efficient use of scientific information and communication resources for professional formation in English. **14.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and analysis of the specific physical properties of dielectrics
7.2. Specific objectives	Study of physical properties of dielectrics. Applications Highlighting the applications of the studied phenomena and of the required experimental set-ups in order to stimulate the creative and critical thinking for solving practical issues.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Electric polarization. Electrical field in dielectrics. Linear response.	Systematic exposition - lecture. Examples.	4 hours
Mechanisms of electric polarization: electronic, ionic, orientational, polarization of space charge.	Systematic exposition - lecture. Examples.	8 hours
Dispersion of optical polarization. Optical properties of dielectrics.	Systematic exposition - lecture. Examples.	4 hours
Relations between optical constants: refraction index, dielectric permitivity, absorption coefficient, conductivity.	Systematic exposition - lecture. Examples.	3 hours
Dynamical properties of dielectrics: dielectric losses, optical conductivity.	Systematic exposition - lecture. Examples.	3 hours
Dielectric spectroscopy: complex impedance, equivalent electrical circuit, Nyquist diagrams.	Systematic exposition - lecture. Examples.	6 hours
References: **8.** I. Bunget, M.Popescu, *Physics of solid dielectrics* (Elsevier, Amsterdam 1984) **9.** A.Jonsker, *Dielectric relaxation in solids*, (Chelsea Dielectric Press, London, 1983). **10.** A.Ioanid, *Probleme de fizica dielectricilor*, (Ed.Univ.Bucuresti, 2002)		

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
	Exposition. Guided work	
Bibliography: 37.		

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Tests of Clausius-Mossotti and Langevin-Debye relations	Guided practical work	4 ore

Analysis of experimental data by Kramers-Kronig transform and by using relations between optical constants	Guided practical work	4 ore
Reflectance spectra	Guided practical work	4 ore
Impedance spectra. Analysis of complex impedance and of equivalent electric circuit	Guided practical work	4 ore
Optical properties of nanostructured systems	Guided practical work	4 ore
Cole-Cole diagrams	Guided practical work	4 ore
Bode and Nyquist diagrams	Guided practical work	4 ore
Bibliography:		
8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The content of this course is designed to lead to the formation of instrumental-application specific competences (use of models, simulation methods and investigation techniques specific to dielectrics) of interest for research institutes in Physics of Materials and education. Because of the importance of the course for modern applications, the content and the teaching methods have been put into correspondence with similar courses taught at other universities as well as with the experimental facilities of the research institutes on the Măgurele platform

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Clarity, coherence and concision of exposition; - Correct use of physical models and of specific mathematical methods; - Ability to exemplify	Written exam	50%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and use of experimental techniques; - Data interpretation	Laboratory colloquium	50%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5 at the written exam Attendance of all practicals and mark 5 at colloquim			

Date	Teacher's name and signature	Tutorials/Practicals instructor(s) name(s) and signature(s)
25.05.2019	Conf. dr. Ciceron Berbecaru	Conf. dr. Ciceron Berbecaru

Date of approval
10.06.2019

Head of department,
Conf. dr. Petrică Cristea

DO.202.1 Computational methods for electronic structures of condensed systems

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	Computational methods for electronic structures of condensed systems							
2.2. Teacher	Conf. dr. George Alexandru NEMNES							
2.3. Tutorials instructor(s)	Conf. dr. George Alexandru NEMNES							
2.4. Practicals instructor(s)								
2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DA**
							Type[2)]	**DO**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	28/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one’s own course notes, manuals, lecture notes, bibliography	20
3.2.2. Research in library, study of electronic resources, field research	20
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	25
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	78
3.4. Total hours per semester	138
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Solid State Physics I and II, Thermodynamics and statistical physics, Electrodynamics, Physical Electronics, Equations of mathematical physics
4.2. competences	38. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)

5.2. for tutorials/practicals	-

6. Acquired specific competencies

Professional competencies	**15.** Identification and adequate use of computational *ab initio* tools for condensed matter systems. **16.** Solving physics problems in given conditions. **17.** Creative use of acquired physical knowledge to understand first principles computational methods. **18.** Analysis and communication of scientific data, communication for physics popularization. **19.** Use and development of specific software tools.
Transversal competencies	**20.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **21.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Understanding of first principles methods and computational tools.
7.2. Specific objectives	- Understanding the approximate methods for many-body systems – perturbative and variational based methods. - Understanding the density functional theory method. - Ability to assimilate, analyse and compare diverse physical phenomena, employing fundamental principles. - Ability of analyse and interpret numerical data, especially concerning band structure calculations and optical properties on the bases of DFT codes and to formulate rigorous theoretical conclusions. - Ability to employ mathematical and numerical models for modelling the physical phenomena. - Ability to use theoretical methods in modelling various physical systems of interest. - Ability to develop computer programs for modelling electronic structure of materials

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Introduction. Classification of many-body approximate methods.	Systematic exposition - lecture. Examples.	2 hours
The problem of electron correlations.	Systematic exposition - lecture. Examples.	4 hours
The density functional theory (DFT). Hohenberg-Kohn theorems.	Systematic exposition - lecture. Examples.	2 hours
Kohn-Sham method. Kohn-Sham equations.	Systematic exposition - lecture. Examples.	2 hours
Functionals for the exchange and correlation terms. The local density approximation (LDA) and local spin density approximation (LSDA). The GGA	Systematic exposition - lecture. Examples.	4 hours

approximation.		
Orbital dependent functionals: self-interaction correction (SIC) and LDA+U approximation. Hybrid functionals.	Systematic exposition - lecture. Examples.	4 hours
Ab initio numerical techniques. Pseudopotentials.	Systematic exposition - lecture. Examples	4 hours
Semilocal pseudopotentials. Ultrasoft pseudopotentials.	Systematic exposition - lecture. Examples	2 hours
Extensions: time dependent density functional theory.	Systematic exposition - lecture. Examples	2 hours
GW approximation. Applications.	Systematic exposition - lecture. Examples	2 hours

References:

11. H. Bruus, K. Flensberg, *Many-Body Quantum Theory in Condensed Matter Physics: An Introduction* (Oxford University Press, Oxford 2004).
12. R.M. Martin, Electronic structure: basic theory and practical methods (Cambridge University Press, Cambridge, 2004).
13. W. Nolting, *Fundamentals of Many-body Physics* (Springer Verlag, Berlin, 2009).

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations
Elaboration of a numerical code to implement the Hartree-Fock method.	Exposition. Guided work	4 ore
SIESTA method: presentation. Advantages and disadvantages of the method.	Exposition. Guided work	4 ore
SIESTA method for band structure calculations in bulk semiconductors and nanostructures.	Exposition. Guided work	4 ore
SIESTA method for investigating defects in semiconductor systems.	Exposition. Guided work	4 ore
Calculation of phonon band structures.	Exposition. Guided work	4 ore
Calculation of optical properties.	Exposition. Guided work	4 ore
Ab initio techniques for magnetic materials.	Exposition. Guided work	4 ore

Bibliography:

SIESTA Manual, https://departments.icmab.es/leem/siesta/

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
	Guided practical work	4 ore

8.4. Research project [if applicable]	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyse specific examples;	Written and oral exam	50%
10.5.1. Tutorials	- Use of specific physical and mathematical methods and techniques;	Homework, research projects	50%
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	xx%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solutions to indicated subjects (for mark 5) in final exam			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
10.10.2019	Conf. dr. George Alexandru Nemnes	Conf. dr. George Alexandru Nemnes

Date of approval

Head of department,
Conf. dr. Petrică Cristea

DO.202.2 Advanced methods in statistical physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	Theoretical and Computational Physics (in English)
1.7. Study mode	Full-time study

2. Course unit

2.1. Course unit title	Advanced methods in statistical physics							
2.2. Teacher				Conf. dr. Alexandru Nicolin				
2.3. Tutorials/Practicals instructor(s)				Conf. dr. Alexandru Nicolin				
2.4. Year of study	II	2.5. Semester	1	2.6. Type of evaluation	E	2.7. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DO**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: Lecture	2	Practicals/Tutorials	2
3.2. Total hours per semester	56	Lecture	28	Practicals/Tutorials	28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	25
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	35
3.2.4. Preparation for exam	4
3.2.5. Other activities	0

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Quantum Statistical Physics, Electrodynamics
4.2. competences	Knowledge about: mechanics, algebra, solving differential equations

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Video projector
5.2. for practicals/tutorials	

6. Specific competences acquired

Professional competences	• Identify and proper use of the main physical laws and principles in a given context: the use of the concepts of statistical quantum mechanics for strongly interacting systems • Solving problems of physics under given conditions • Use of the physical principles and laws for solving theoretical or practical problems with qualified tutoring • Rigorous knowledge of quantum theory, concepts, notions and problems in the area of modern nuclear physics • Ability to use this knowledge in interpretation of experimental result • Understanding the role of the interaction, of the particle nature and of the dimensionality over the dynamical properties • Developing the computational abilities and a sound theoretical knowledge of the studied problems
Transversal competences	• Efficient use of sources of information and communication resources and training assistance in a foreign language • Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	- Understanding the specific feature of the quantum systems composed from strongly correlated identical particles Developing the capability to assimilate, analyse and compare diverse phenomena, starting from basic principles - Developing the ability to analyse and interpret the experimental data and to formulate rigorous theoretical conclusions - Developing the ability to apply mathematical models and adequate numerical procedures
7.2. Specific objectives	Gain the ability to work with theoretical methods of quantum many-body systems adapted to strongly interacting systems Acquire the skills to describe and calculate the physical properties of quantum many-body systems involved in different physical conditions.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
The formalism of the Green functions: General properties of Green functions (symmetry, Lehman representations), physical interpretation for the retarded Green function.	Systematic exposition - lecture. Examples	8 hours
The formalism of the density functional: The theory of the density functional. Hohenberg-Kohn theorems. The Kohn-Sham equations. Approximate functionals. Introduction in the theory of the time dependent density functional.	Systematic exposition - lecture. Examples	6 hours
The dynamics of the Bose-Einstein condensate The Gross-Pitaevskii equation. Elementary excitations and collective modes. Solitons. Traps for condensates for finite temperature.	Systematic exposition - lecture. Examples	6 hours
From the integral Hall effect to the fractional Hall effect : Strong correlated systems and the	Systematic exposition - lecture. Examples	6 hours

quasiparticle concept. Laughlin theory. The theory of compound fermions.		
Ginzburg–Landau theory of superconductivity. Basic equations. From type-I superconductor to type-II superconductors.	Systematic exposition - lecture. Examples	4 hours

Bibliography:

22. E. Lipparini, *Modern many-particle physics. Atomic gases, quantum dots and quantum fluids*, World Scientific, 2003
23. R.G. Paar, W. Yang, *Density functional theory for atoms and molecules,* Oxford UP,*1989*
24. C.A. Ullrich, *Time-Dependent Density Functional Theory,* Oxford UP, 2012
25. J.K. Jain, *Composite fermions*, Cambridge UP, 2007
26. T. Chakraborty, P. Pietilainen, The *quantum Hall effects, Fractional and Integral*, Springer 1995
27. C.J. Pethick, H. Smith, *Bose-Einstein Condensation in Dilute Gases*, Cambridge UP, 2008
28. Z.F. Ezawa, *Quantum Hall effects,* World Scientific, 2007
29. Fetter A.L. , J.D. Walecka, *Quantum theory of Many Particle systems* (McGraw Hill, New-York)
30. W. Buckel, R. Kleiner, *Superconductivity: Fundamentals and Applications*, WILEY-VCH Verlag GmbH 2004

8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Galitskii-Migdal theorems. The relation with the observables. Differential equations. Correlation functions:definition, general properties, the similarity with the Green functions.	Problem solving	6 hours
Applications of the Green formalism for various systems. The Thomas-Fermi approximation and its extensions	Problem solving	4 hours
Applications of Density Functional Theory	Problem solving	4 hours
Collective dynamics of Bose-Einstein condensates	Problem solving	4 hours
The theory of compound fermions.	Problem solving	4 hours
Superconductivity: surface energy and thermodynamic critical field in Ghinzburg-Landau theory. Vortex lattice. Josephson tunnelling.	Problem solving	6 hours

Bibliography:
A.S. Alexandrov *Theory of Superconductivity .From Weak to Strong Coupling,* IOP Publishing Ltd 2003

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical competences, which are fundamental for a Master student in the field of modern physics, corresponding to national and international standards. The contents is in line with the requirement of the main employers of research institutes and universities.

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- Clarity and coherence of exposition - Correct use of the methods/	Written test and oral examination	60%

	physical models - The ability to give specific examples		
10.5.1. Tutorials	- Ability to use specific problem solving methods	Homeworks	40%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) At least 50% of exam score and of homeworks.			

Date
10.06.2019

Teacher's name and signature

Conf. dr. Alexandru Nicolin

Practicals/Tutorials instructor(s) name(s) and signature(s)

Conf. dr. Alexandru Nicolin

Date of approval
10.06.2019

Head of Department

Prof.dr. Virgil Baran

DO.207.2 Physics of Semiconductor Devices

1. Description of the program

1.1. Higher education institution	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid-State Physics, and Biophysics
1.4. Field of Study	Physics
1.5. Level	Master of Science
1.6. Academic Program Title	Physics of Advanced Materials and Nanostructures
1.7. Attendance	Required according to the schedule

2. Information on course

2.1. Title	**Physics of Semiconductor Devices**								
2.2. Instructor (lectures)	Associate Prof. dr. Petrică Cristea								
2.3. Instructor (recitation classes))									
2.4. Instructor (practical activities)	Associate Prof. dr. Petrică Cristea								
2.5. Year of study	2	2.6. Semester	4	2.7. Evaluation	E	2.8. Course type	Content[1)]	**DS**	
							Attendance[2)]	**DO**	

[1)] thoroughgoing study (DA), synthesis discipline (DS);
[2)] mandatory discipline (DI), optional discipline (DO), facultative discipline (DFac)

3. Time allocated (hrs/semester)

3.1. hrs./week	4	lectures	2	practical activities	2
3.2. Total hrs./semester	56	lectures	28	practical activities	28
Time distribution on student activities					hrs.
3.2.1. Reading of manuals, lecture notes, references					20
3.2.2 Documenting at library and using electronic resources					20
3.2.3. Completing home work for practical activities and writting short reports on experiments					25
3.2.4.Evaluations					4
3.2.5. Other activities					

3.3. # hrs. allocated to individual study	65
3.4. # hrs./semester	125
3.5. Allocated credits to the course	5

4. Prerequisites

4.1. curriculum	Attending the lectures on: *Electricity and Magnetism, Thermodynamics and Statistical physics, Electronics, Quantum Mechanics, Solid-State Physics*
4.2. Skills	Use of software packages for data analysis and processing

5. Requirements

5.1. lectures	Multimedia room (video projector)
5.2. for conducting the practical activities	- Multimedia room (video projector)- 3 to4 pc stations (minimum core I3) - OS Linux sau Windows 7

6. Specific skills acquired

Professional skills	**31.** Using the laws of classical electromagnetism and of the statistical notions to describe the semi-classical and quantum behavior of modern semiconductor devices. **32.** Creatively applying the knowledge acquired in order to understand and model the parameters and characteristics of modern semiconductor devices. **33.** Communicate and analyze didactic and scientific information on physics. **34.** Ability to make use of specific scientific software packages.
Attitudinal skills	**35.** Efficient use of information sources, communication resources and vocational training, including in a language of international circulation. **36.** Carrying out professional tasks in an efficient and responsible manner, in compliance with the specific legislation, ethics and deontology.

7. The course aim at (based on the grid of specific skills accumulated)

7.1. General	Familiarize students with the operating principles and the applications of the main semiconductor devices used by modern electronic circuits.
7.2. Specific	Understanding of the general principles underlying the operation of semiconductor devices. Introducind students to modern technologies related to synthesis of semiconductor materials. Familiarize students with software packages used in semiconductor device modeling.

8. Content

8.1. Lectures	Teaching method	hrs.
Types of semiconductor materials	Systematic presentation - lecture	2
Main technologies dedicated to semiconductor materials	Systematic presentation - lecture	2
p-n Junctions	Systematic presentation - lecture	2
Bipolar transistors	Systematic presentation - lecture	2
MOSFET structures	Systematic presentation - lecture	2
Structuri MESFET si MODFET	Systematic presentation - lecture	2
Tunnel Diodes	Systematic presentation - lecture	4
Resonant Devices	Systematic presentation - lecture	4
Photonic devices	Systematic presentation - lecture	2
Modeling of Semiconductor Devices. Processing of the results and extracting physical data of interest	Systematic presentation - lecture	6

References:

1. S. M. Sze and Kwok K. Ng, *Physics of Semiconductor Devices*, Wiley Interscience 2007
2. S. M. Sze, *Semiconductor Devices, Physics and Technology*, John Wiley&Sons 2002
3. M. Dragoman, D. Dragoman – *Nanoelectronics: Principles and Devices*, Artech House, 2nd edition, Boston, U.S.A., 2009
4. I. Munteanu, *Fizica solidului*, Editura Univ. Bucuresti, 1993
5. L. Ion, *Solid-State Physics* - Lecture Notes

6. P. Cristea, *Dispozitive Electronice Speciale*, Vol. 1, Editura Univ. Bucuresti, 1999		
8.2. Recitation classes [topics discussed]	Teaching method	hrs.
8.3. Practical activities [laboratory topics and projects]	Teaching method	hrs.
Numerical study of the influence of doping on electrical properties	Assisted practical activity	2
Numerical study of p-n junctions and multi-junction structures. The influence of size reduction	Assisted practical activity	4
Numerical study of bipolar transistors	Assisted practical activity	8
Simulation and design of MOSFET structures	Assisted practical activity	4
Simulation and design of MODFET structures	Assisted practical activity	6
Simulation and design of resonant structures	Assisted practical activity	4
References **10.** S. M. Sze, *Semiconductor Devices, Physics and Technology*, John Wiley&Sons 2002*VMD* **11.** P. Cristea, *Dispozitive Electronice Speciale*, Vol. 1, Editura Univ. Bucuresti, 1999 **12.** nanoHUB: https://nanohub.org/		
8.4. Project [only for those disciplines having a semester project included in the curriculum]	Teaching method	hrs.
References:		

9. Corroborating the contents of the discipline with the expectations of main representatives of epistemic communities, professional associations and representative employers in the field related to the program

To decide about the content, the teaching/learning methods, the instructor made the content compatible to similar subjects taught at universities in the country and abroad (University of Illinois, University of Cambridge, MIT). The content of the discipline complies to the requirements of employment in research institutes in physics.

10. Evaluations and gradind

Type of activity	10.1. Evaluation items	10.2. Evaluation methods	10.3. Pondere din nota finală
10.4. Lectures	- Exposure clarity, coherence and conciseness - Understand correctly the principles, models, formulas and relations of calculation - Ability to provide and make use of relevant arguments	oral examination	50%
10.5.1. Recitation classes			

10.5.2. Practical activities	- Ability to use software packages as WinGreen, RTD, HEMT, SelfHEMT software packages	Practical test	50%
10.5.3. Project [[only for those disciplines having a semester project included in the curriculum]]			
10.6. Minimum standard of performance			
Getting a minimum score of 5 Completing all required practical work and passing of the practical test (at least a score 5) Correct answers for the required questions at the final (at least a score 5).			

Completed on 10.06.2019

Instructor's signature

Conf. dr. Petrica Cristea

Head of the Department,
Associate Prof. dr. Petrică Cristea

DO.204.2 Electrical and optical characterization of semiconductors

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	**Physics of mesoscopic systems**							
2.2. Teacher	Conf.dr. Florin Stanculescu							
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)	Lect. Dr. Sorina Iftimie							
2.5. Year of study	1	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DO**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	0/2
3.2. Total hours per semester	56	distribution: lecture	28	Tutorials/Practicals	0/28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	25
3.2.2. Research in library, study of electronic resources, field research	25
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	40
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Optics, Equations of Mathematical Physics, Solid State Physics
4.2. competences	39. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	-laboratory set-ups for electrical and optical characterization of semiconductors

6. Acquired specific competencies

Professional competencies	**37.** Identificartion and adequate use of physics laws in a given context; identification and adequate use of notions and specific physics laws for semiconductors. **38.** Solving physics problems in given conditions. **39.** Creative use of acquired physical knowledge to understand and to construct models for physical processes and properties of semiconductors. **40.** Analysis and communication of scientific data, communication for physics popularisation. **41.** Use and development of specific software tools.
Transversal competencies	**42.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **43.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Introduction and analysis of the physical methods in semiconductor characterisation
7.2. Specific objectives	Study of structure of measurement systems and of uncertainty in semiconductor measurements. Analysis of most important electrical characterisation methods of semiconductors. Analysis of most important optical characterisation methods of semiconductors. Highlighting of essential problems in understanding of specific phenomena, in order to stimulate creative and critical thinking în solving problems.

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Evaluation of the uncertainty of measurement;	Systematic exposition - lecture. Examples.	2 hours
Noise in measurement systems;	Systematic exposition - lecture. Examples.	2 hours
Resistivity measurement (direct method, two probe method, four probe method, van de Pauw method). Temperature dependence;	Systematic exposition - lecture. Examples.	6 hours
Determination of the carrier concentration, the type of conduction and the mobility of the charge carriers;	Systematic exposition - lecture. Examples.	4 hours
Determination of the lifetime and the diffusion length of minority carriers;	Systematic exposition - lecture. Examples.	2 hours
Characterization of the electrically active centers by the DLTS method;	Systematic exposition - lecture. Examples.	2 hours
Interaction of electromagnetic radiation with semiconductors. Optical coefficients;	Systematic exposition - lecture. Examples.	2 hours
Spectrophotometric methods for the characterization of	Systematic exposition -	2 hours

semiconductors;	lecture. Examples.	
Measurement of the impurities concentration and of the band gap energy;	Systematic exposition - lecture. Examples.	2 hours
Ellipsometric methods for the characterization of semiconductors;	Systematic exposition - lecture. Examples.	2 hours
SUPPLEMENTARY SUBJECTS		
Roughness and granulation analysis;	Systematic exposition - lecture. Examples.	1 hours
The use of SNOM and confocal microscopy in the characterization of semiconductors;	Systematic exposition - lecture. Examples.	1 hours

References:

14. Alain C. Diebold „Handbook of Silicon Semiconductor Metrology", Marcel Dekker, 2001;
15. K Schroder, Semiconductor Material And Device Characterization, Wiley, 2006
16. H. Czichos, T. Sait, Leslie Smith, „Springer Handbook of Materials Measurement Methods", Springer 2006;
17. W.R.Runyan, T.J.Shaffner, "Semiconductor Measurements and Instrumentation", McGraw-Hill, NY,1997;
18. John G. Webster , „The Measurement, Instrumentation, and Sensors Handbook", CRC Press 1999;
19. Walt Boyes, „Instrumentation Reference Book", BUTTERWORTH HEINEMANN (Elsevier), 2003;
20. Annual Book of ASTM Standards, vol. 10.04 - Electronics (I) 2006
21. Annual Book of ASTM Standards, vol. 10.05 - Electronics (II) 2006
22. Semyon G. Rabinovich, "Evaluating Measurement Accuracy", Springer, 2010
23. Toru Yoshizawa, "Handbook of Optical Metrology", CRC Press Taylor & Francis 2009
24. Paolo Fornasini, "The Uncertainty in Physical Measurements", Springer, 2008
25. Roy M. Howard, "Principles of Random Signal Analysis and Low Noise Design", Wiley 2002
26. Horst Czichos, Tetsuya Saito, Leslie Smith „Springer Handbook of Metrology and Testing", Springer 2011;
27. Fridman, A.E., „The Quality of Measurements", Springer 2012;
28. Vladimir Murashov, John Howard, „Nanotechnology Standards", Springer 2011;

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations

Bibliography:

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Determination of semiconductor resistivity by direct method, method of two probes, method of four probes, method of van Pauw. Evaluation of the measurement uncertainty of resistivity	Guided practical work	4 hours
Determination of the type conduction by Hall effect, by the hot / cold probe method, the rectifier contact method and the three probe method	Guided practical work	4 hours

Determination of mobility	Guided practical work	4 hours
Measurement of carrier concentration by CV method.	Guided practical work	4 hours
Determination of the life time by the method of photoconduction relaxation	Guided practical work	4 hours
Determination of some physical quantities, characteristics of semiconductors, by transmission spectrophotometry	Guided practical work	4 hours
ADDITIONAL WORKS		
Analysis of roughness and granulation by SNOM, AFM, and SEM microscopy methods;	Guided practical work	4 hours
8.4. Research project [if applicable]	Teaching and learning techniques	Observations

Bibliography:

Alain C. Diebold „Handbook of Silicon Semiconductor Metrology”, Marcel Dekker, 2001;
K Schroder, Semiconductor Material And Device Characterization, Wiley, 2006
W.R.Runyan, T.J.Shaffner, "Semiconductor Measurements and Instrumentation", McGraw-Hill, NY,1997;
Annual Book of ASTM Standards, vol. 10.04 - Electronics (I) 2006
Annual Book of ASTM Standards, vol. 10.05 - Electronics (II) 2006
Semyon G. Rabinovich, "Evaluating Measurement Accuracy", Springer, 2010
Toru Yoshizawa, "Handbook of Optical Metrology", CRC Press Taylor & Francis 2009
Paolo Fornasini, "The Uncertainty in Physical Measurements", Springer, 2008

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyse specific examples;	Written and oral exam	50%
10.5.1. Tutorials			50%
10.5.2. Practicals	- Knowledge and correct use of	Colloquium, Homework,	50x%

	specific experimental techniques - Data processing and analysis;		
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date | Teacher's name and signature | Practicals/Tutorials instructor(s) name(s) and signature(s)

25.06.2019 | Conf.dr. Florin Stanculescu | Lect.dr.Sorina Iftimie

Date of approval

Head of department,
Conf. dr. Petrică Cristea

DO.207.1 Special electronic and opto-electronic devices

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title	Special electronic and opto-electronic devices								
2.2. Teacher				Prof. univ. dr. Stefan ANTOHE					
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)				Prof. univ. dr. Stefan ANTOHE					
2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DS**	
							Type[2]	**DO**	

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	0/2
3.2. Total hours per semester	40	distribution: lecture	20	Tutorials/Practicals	0/20
Distribution of estimated time for study					hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography					25
3.2.2. Research in library, study of electronic resources, field research					25
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks					31
3.2.4. Examination					4
3.2.5. Other activities					

3.3. Total hours of individual study	81
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Electricity and magnetism, Physics of Semiconductors, Physics of Organic Thin Films
4.2. competences	Electrical measurements. Using of software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	-Experimental setups from laboratories of MDEO Center

6. Acquired specific competencies

Professional competencies	**44.** Identificartion and adequate use of physics laws in a given context; identification and adequate use of notions and specific physics laws for electronic devices based on both organic and inorganic thin films. **45.** Understanding the mechanism of charge carrier transport at interfaces: Metal/Semiconductor; Semiconductor/Semiconductor. **46.** Knowledge to understanding of the physical processes in hybrid structures based on Organic/Inorganic thin films. **47.** Analysis and communication of scientific data, communication for physics popularisation.
Transversal competencies	**48.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology. **49.** Efficient use of the available scientific information resources (specialized books research papers, internet search) **50.** Ability to communicate in English the scientific results to a broad audience in a rigorous and clearly structured manner

7. Course objectives

7.1. General objective	Study of specific charge transport mecanisms in the electronic and optoelectronic devices based on organic and hybrid Organic/Inorganic thin films
7.2. Specific objectives	Theory of Depletion Layer at interface Metal/Semiconductor Study of charge transport mecanism at Metal/Semiconductor Interface. Analysis of specific charge transport models in Organic/Inorganic Interfaces. Highlighting of essential problems in understanding of excitonic mechanism for photogeneration in the organic photovoltaic cells

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Phyisical Proccesses at Metal/Semiconductor Interface: -Classification of the M/S contacts (ohmic contact, blocking contact) ; - Theory of the depletion layer; - Transport mechanism of the charge carriers through the M/S contact: (i) thermionic emission model of Bethe; (ii) Difussion model of Schottky; Mixt theory of thermionic emission and diffusion of Krowel and Sze.	Systematic exposition - lecture. Examples.	hours
Theory of Space Charge Limited Currents (SCLC) – Space Charge Limited Curents – conditions of appearence **13.** Curent –Voltage (I-V) characteristics of SCLC currents in a free traps solid **14.** I-V characteristics of SCLC in a solid with a discret distribution of traps in the Band Gap (BG) **15.** I-V characteristics of SCLC in a solid with an uniform trap distribution the (BG) **16.** I-V characteristics of SCLC in a solid with an exponential trap distribution the (BG)	Systematic exposition - lecture. Examples.	6 hours
Electrical properties of Organic/Inorganic Diodes (OI) **17.** Charge carrier transport mechanism in O/IDiodes **18.** The bipolar Current-Voltage (I-V) Characteristics	Systematic exposition - lecture. Examples.	4 hours

of OI Diodes **19.** The O/I Admitance characteristics for a large range of frequency **20.** Semiconducting Organic Inorganic Surface Analysis Spectroscopy (SOISAS)		
Organic Photovoltaic Cells -Photovoltaic effect in First generation of PV -Photovoltaic Cells from Second generation of SC (based on A2-B6 compounds) - Photovoltaic Cells from Third generation of SC (based on organic semiconductors (i) Small molecules (ii) polymers and (iii) Bulkheterojunction basedon polymeric blends (iv) Photovoltaic Cells from forth generation of SC (based on nanostructured inorganic electrode sensitized with an organic semiconductor	Systematic exposition - lecture. Examples.	4 hours

Bibliography:

29. *S.M. Sze, Physics of Semiconductor Devices (Wiley, New York, 1969).*

30. *M.A. Lampert. Reports on Progress in Physics, 27:329, 1964.*

31. ***S. Antohe**, Materiale și Dispozitive Electronice Organice (Editura. Universității din București, București, 1996)*

32. ***S. Antohe**, Electronic and Optoelectronic Devices Based on Organic Thin Films, in Handbook of Organic Electronics and Photonics: Electronic Materials and Devices, H. Singh-Nalwa (Ed.) (American Scientific Publishers, Los Angeles, California, USA, 2006), vol 1*

8.2. Laboratory [main subjects of practical works]	Teaching and learning techniques	Observations
Non-Ohmic effect in M1/organic semiconductor/M2 structures	Measurements and data analysis and processing	4 ore
Determination of charge carrier transport parameters in an organic thin film	Measurements and data analysis and processing	4 ore
Measuremets of I-V characteristics at forward and reverse vias of OI diodes: Ag/p-Si/PTCDI/In și Ag/p-Si/CuPc/Cu with determination of depletion layer parameters	Measurements and data analysis and processing	4 ore
Measurement of I-V characteristic in the dark of a Photovoltaic cell with determination of series resistance Rs, shunt resistance, ideality factor n and saturation current Is	Measurements and data analysis and processing	4 ore
Measurement of I-V characteristic in forth quadrant, at illumination in A.M. 1.5 conditions of a Photovoltaic cell with determination of typical parameters as photoelement: Uoc, Isc, FF, EQE, PCE .	Measurements and data analysis and processing	4 ore

Bibliography:

40. ***S. Antohe**. Physica Status Solidi A, 136:401, 1993.*

41. *Three-Layered Photovoltaic Cell With an Enlarged Photoactive Region of Codeposited Dyes, **S. Antohe**, V.Ruxandra, L.Tugulea,V.Gheorghe, D. Ionaşcu, **Journal de Physique III France 6, 1133-1144, (1996)***

42. ***S. Antohe**, L. Ion, F. Stanculescu, S. Iftimie, A. Radu and V. A. Antohe, "Fizica si tehnologia materialelor semiconductoare – Lucrari practice", Ars Docendi, Universitatea din Bucuresti, 165 pages, 2016, ISBN: 978-973-558-940-0*

43. *A critical review of photovoltaic cells based on organic monomeric and polymeric thin film heterojunctions By:**Antohe, S;** Iftimie, S; Hrostea, L; Antohe, VA[1] ; Girtan, M, **THIN SOLID FILMS** Volume: 642 Pages: 219-231 Published: NOV 30 2017*

8.3. Research project [if applicable]	Teaching and learning techniques	Observations

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (University of Kent at canterbury, Hanover University, University of Angers. The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific methods; - Ability to analyse specific examples;	Written and oral exam	50%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	50%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher's name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. univ. dr. Stefan ANTOHE	Prof. univ. dr. Stefan ANTOHE

Head of department,

Date of approval
10.06.2019

Conf. dr. Petrică Cristea

DO.207.2 Physics and Technology of Thin Films

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Graduate/Master
1.6. Study program/Qualification	Physics of advanced materials and nanostructures (in English)/Physics of advanced materials and nanostructures
1.7. Mode of study	Full-time study

2. Course unit

2.1. Course title			**Physics and technology of thin films**						
2.2. Teacher				Prof. dr. Ştefan Antohe					
2.3. Tutorials instructor(s)									
2.4. Practicals instructor(s)				Prof. dr. Ştefan Antohe					
2.5. Year of study	2	2.6. Semester	2	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]		**DS**
							Type[2)]		**DO**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: lecture	2	Tutorials/Practicals	2/0
3.2. Total hours per semester	40	distribution: lecture	20	Tutorials/Practicals	20/0

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	21
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	30
3.2.4. Examination	4
3.2.5. Other activities	

3.3. Total hours of individual study	81
3.4. Total hours per semester	125
3.5. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Solid State Physics I, Optics, Electronics, Electrodynamics
4.2. competences	44. Understanding the structural properties of thin films 45. Knowledge and understanding of optical phenomena and charge carriers transport mechanisms of thin films 46. Knowledge and understanding of the physical processes and phenomena typical for thin films based devices 47. Understanding underlying physical phenomena 48. Ability to analyze and understand relevant experimental data and to formulate rigorous conclusions

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, video-projector, internet connection)
5.2. for tutorials/practical classes	Experimental set-ups in Thin Films Laboratory and Nanotechnology Laboratory of Materials and Devices for Electronics and Optoelectronics R&D Center

6. Acquired specific competencies

Professional competencies	**51.** Knowledge and explanation of the physical properties of thin films **52.** Knowledge and explanation of the physical properties of thin films based devices **53.** Development of specific capacities of analysis using fundamental processes and phenomena in Physics **54.** Development of the ability to create and properly use of mathematical and numerical models applied to thin films and their applications **55.** Analysis and communication of scientific data. **56.** Use and development of specific laboratory equipments.
Transversal competencies	**57.** Efficient use of scientific information resources for professional formation in English. **58.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Knowledge and understanding of the physical properties of thin films and their electronic and optoelectronic applications
7.2. Specific objectives	Inorganic materials based thin films: A2B6 compounds and A3B5 compounds Deposition methods of inorganic thin films Study of the structural properties of inorganic thin films Study of the morphological and optical properties of inorganic thin films Study of the electrical properties of inorganic thin films Organic materials based thin films: conductive polymers Study of the structural properties of organic thin films Study of the morphological and optical properties of organic thin films Study of the electrical properties of organic thin films Thin films based electronic and optoelectronic devices: transistors, photo-diodes, photovoltaic structures, detectors

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations
Inorganic materials based thin films. Introductory information. General presentation.	Systematic exposition - lecture.	2 hours
Organic materials based thin films. Introductory information. General presentation.	Systematic exposition - lecture.	2 hours
Thermal vacuum evaporation: working principle; specific processes and phenomena for A2B6 compounds and for A3B5 compounds; adsorption processes; condensation processes; appropriateness of the method.	Systematic exposition - lecture. Examples.	4 hours
Magnetron sputtering (RF and DC modes): working principle, specific process and phenomena, working parameters, the influence of working gas (non-reactive/reactive), appropriateness of the method.	Systematic exposition - lecture. Examples.	4 hours
Chemical vapor deposition: working principle,	Systematic exposition -	4 hours

diffusion phenomena, specific chemical processes involved, capacitive plasmas, appropriateness of the method.	lecture. Examples.	
Spin-coating: working principle, kinetics of solutions; appropriateness of the method.	Systematic exposition - lecture. Examples.	4 hours
Study of the structural properties of inorganic and organic materials based thin films.	Systematic exposition - lecture. Examples.	2 hours
Study of morphological and optical properties of inorganic and organic materials based thin films.	Systematic exposition - lecture. Examples.	2 hours
Study of the electrical properties of inorganic and organic materials based thin films.	Systematic exposition - lecture. Examples.	2 hours
Resume of lectures.	Systematic exposition - lecture. Examples.	2 hours

References:

33. S. Antohe, *Electronic and Optoelectronic Devices Based on Organic Thin Films*, in *Handbook of Organic Electronics and Photonics: Electronic Materials and Devices*, H. Singh-Nalwa (Ed.) (American Scientific Publishers, Los Angeles, California, USA, 2006).

34. S. Antohe, S. Iftimie, L. Hrostea, V.A. Antohe, M. Girtan, *A critical review of photovoltaic cells based on organic monomeric and polymeric thin film heterojunctions* in *Thin Solid Films* 642, 219-231, 2017.

35. M. Ohring, *Materials Science of Thin Films*, Academic Press, London, UK, 2002.

36. Lecture notes available on http://solid.fizica.unibuc.ro.

37. J. George, *Preparation of thin films*, Cochin University of Science and Technology, Cochin, Kerala, India, 1992.

8.2. Tutorials [main tutorial subjects]	Teaching and learning techniques	Observations

8.3. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Deposition of thin films by thermal vacuum evaporation	Guided practical work	4 hours
Deposition of thin films by magnetron sputtering (RF and DC)	Guided practical work	4 hours
Growth of thin films by chemical vapor deposition	Guided practical work	4 hours
Growth of thin films by spin-coating	Guided practical work	4 hours
Study of the structural properties of inorganic and organic thin films: X-ray diffraction and X-ray reflectometry	Guided practical work	2 hours
Study of the morphological and optical properties of inorganic and organic thin films: atomic force microscopy, spectroscopic methods – absorption, transmission, reflection, ellipsometry	Guided practical work	2 hours
Study of the electrical properties of inorganic and organic thin films: current-voltage characteristics, van der Pauw measurements, Hall effect measurements	Guided practical work	2 hours
Hand-on lab test & quiz	Group project	2 hours

8.4. Research project [if applicable]	Teaching and learning techniques	Observations

References:

21. Laboratory notes

22. M.P. Soriaga, J. Stickney, L.A. Bottomley, Y-G. Kim, *Thin Films. Preparation. Characterization. Applications.*, Spronger Science + Business Media, LLC, 2002.

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

This course unit develops some theoretical and practical competencies and skills corresponding to national and international standards, which are important for a master student in the field of modern Physics and technology. The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union (Universite Paris-Sud, University of Cambridge, Universite Catholique Louvain-la-Neuve). The contents are in line with the requirements of the main employers of the graduates (industry, research institutes, high-school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight în final mark
10.4. Lecture	- Explicitness, coherence and concision of scientific statements; - Correct use of physical models and of specific mathematical methods; - Ability to analyze specific examples;	Written exam	70%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge and correct use of specific experimental techniques - Data processing and analysis;	Colloquium	30%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 5.			

Date	Teacher(s) name and signature	Practicals/Tutorials instructor(s) name(s) and signature(s)
25.05.2019	Prof. dr. Ştefan Antohe	Prof. dr. Ştefan Antohe

Date of approval
10.06.2019

Head of department,
Assoc. Prof. dr. Petrică Cristea

III. Optional course units

DFC.113 Phase transitions in condensed matter

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	Physics of materials and nanostructures
1.7. Study mode	Full-time study

2. Course unit

2.1. Course unit title	**Interaction of laser radiation with matter**							
2.2. Teacher				Conf. dr. Ciceron Berbecaru				
2.3. Tutorials/Practicals instructor(s)				Conf. dr. Ciceron Berbecaru				
2.5. Year of study	I	2.6 Semester	II	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DA**
							Type[2)]	**DFC**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: Lecture	2	Practicals/Tutorials	1/1
3.2. Total hours per semester	56	Lecture	28	Practicals/Tutorials	14/14

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	15
3.2.2. Research in library, study of electronic resources, field research	15
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	10
3.2.4. Preparation for exam	4
3.2.5. Other activities	0

3.3. Total hours of individual study	40
3.4. Total hours per semester	100
3.5. ECTS	4

4. Prerequisites (if necessary)

4.1. curriculum	Solid State Physics, Quantum mechanics, Thermodynamics and statistical physics
4.2. competences	Using of specialized software for data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Computer, Video projector
5.2. for practicals/tutorials	Specialized laboratory setups

6. Specific competences acquired

Professional competences	- Knowledge of physical phenomena associated to phase transitions - Ability of comparing and analyzing physical phenomena based on fundamental principles - Communication and analysis of scientific and general information in physics
Transversal competences	- Efficient use of sources of information and communication resources and training assistance in a foreign language. - accomplishment of professional tasks in a professional way, assuming an ethical conduct in scientific research;

7. Course objectives

7.1. General objective	Understanding of physical phenomena associated to phase transitions
7.2. Specific objectives	Highlighting essential aspects for understanding of phenomena which allows for creative solutions to physical problems

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
<u>Landau theory of phase transitions</u> Symmetry breaking. Order parameter. Landau's thermodynamic theory. Onstein-Zernike theory – gaussian approximation. Landa-Ginzburg criterion. Introduction to critical phenomena	Systematic exposition - lecture. Examples	6 hours
<u>Dielectric materials – phase transitions</u> Permitivity and dielelctric losses. Debye theory. Frequency and temperature dependence of complex dielectric function. Applications.	Systematic exposition - lecture. Examples	8 hours
<u>Phase transitions în ferroelectric materials</u>. Definition, classifications, structure, properties. Phase transitions. Spontaneous polarization and dielectric function în 1-st order phase transitions. Ferroelectric domains. Polarization and dielectric function în phase în 2-nd order phase transitions.	Systematic exposition - lecture. Examples	8 hours
<u>Ferroelectric crystals.</u> Domain structure. Effects of temperature and external electric field. Investigation methods. Ferroelectric ceramics for electronics. Phase diagrams. Pyroelectric materials. Multiferroics.	Systematic exposition - lecture. Examples	6 hours

Bibliography:

59. M. Dondera, V. Florescu. *Capitole de fizica atomica teoretica, Ed. UB, 2005.*
60. F.H.M. Faisal, *Theory of multiphotonic processes*, Plenum Press, 1987
61. C. J. Joachain, N. Kylstra, R. M. Potvliege, *Atoms in intense laser fields*, Cambridge University Press, 2012.
62. **W. Greiner, *Quantum Mechanics: Special Chapters*, Springer, 1998**

8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Phase transitions with order parameter. Examples	Lecture. Problem solving.	6 hours

Critical phenomena. Critical exponents. Examples.	Lecture. Problem solving.	4 hours
Ferroelectric and piesoelectric crystals. Structure of material tensors.	Lecture. Problem solving.	4 hours
8.2. Practicals [research subjects, projects]	Teaching and learning techniques	Observations
Temperature dependence of spontaneous polarization for 1-st and 2-nd order phase transitions	Guided practical activity	2 hours
Temperature dependence of dielectric functions near phase transition points.	Guided practical activity	4 hours
Frequency dependence of dielectric function. Dielectric spectroscopy.	Guided practical activity	4 hours
Ferroelectric materials. TGS – crystal growth and properties.	Guided practical activity	4 hours

Bibliography:
1. C. Cohen-Tannoudji, J. Dupont-Roc, G. Grynberg, *Atom-Photon Interactions*, Wiley-VCH Verlag, 2004.
2. J. D. Jackson Classical Electrodynamics (Wiley, 1962).
3. M. Boca, Lecture notes

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The contents and teaching methods were selected after an analysis of the contents of similar course units in the syllabus of other universities (LMU, KTH) . The contents are in line with the requirements/expectations of the main employers of the graduates (research, academic, secondary school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- coherence and clarity of exposition - correct use of physical models and theories	Written test/oral examination	50%
10.5.1. Tutorials			
10.5.2. Practicals	- Knowledge of experimental techniques - Analysis of experimental results	Colloquium	50%
10.5.3. Project [if applicable]			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) All experiments in practicals have to be performed. Correct presentation of the subjects indicated for mark 5 in the final exams.			

Date 25.05.2019

Teacher's name and signature
Conf. dr. Ciceron Berbecaru

Practicals/Tutorials instructor(s) name(s) and signature(s)
Conf. dr. Ciceron Berbecaru

Date of approval

Head of Department

10.06.2019 Conf. dr. Petrică Cristea

DFC.114 Interaction of laser radiation with matter

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	Theoretical and Computational Physics (in English)
1.7. Study mode	Full-time study

2. Course unit

2.1. Course unit title	**Interaction of laser radiation with matter**							
2.2. Teacher				Conf. dr. Madalina Boca				
2.3. Tutorials/Practicals instructor(s)				Conf. dr. Madalina Boca				
2.5. Year of study	I	2.6 Semester	II	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1)]	**DA**
							Type[2)]	**DFC**

[1)] deepening (DA), speciality/fundamental (DS);
[2)] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: Lecture	2	Practicals/Tutorials	2
3.2. Total hours per semester	56	Lecture	28	Practicals/Tutorials	28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	15
3.2.2. Research in library, study of electronic resources, field research	15
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks	10
3.2.4. Preparation for exam	4
3.2.5. Other activities	0

3.3. Total hours of individual study	40
3.4. Total hours per semester	100
3.5. ECTS	4

4. Prerequisites (if necessary)

4.1. curriculum	Electrodynamics and relativity theory, Quantum mechanics
4.2. competences	Numerical / using of approximation methods for solving differential equations

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Computer, Video projector
5.2. for practicals/tutorials	**Computer, Video projector**

6. Specific competences acquired

Professional competences	- Identify and proper use of the main physical laws and principles in a given context. Identify and proper use of specific laws for simple systems in interaction with the electromagnetic field. -solving pf physics problems in given conditions - Using the acquired knowledge for understanding / modeling of processes in electromagnetic fields - Communication and analysis of didactic, scientific and general information in physics
Transversal competences	- Efficient use of sources of information and communication resources and training assistance in a foreign language. - accomplishment of professional tasks in an professional way, assuming an ethical conduct in scientific research;

7. Course objectives

7.1. General objective	Presentation of the main processes in the interaction of radiation with the substance
7.2. Specific objectives	Understanding the classical / quantum theory of the interaction of electromagnetic radiation with matter - Understanding the evolution in time of some systems in interaction with the electromagnetic field - The ability to use approximate / numerical mathematical models in the analysis of the interaction of electromagnetic radiation with matter

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Physical processes in electromagnetic fields: overview.	Systematic exposition - lecture. Examples	2 hours
Electromagnetic waves and photons; introduction	Systematic exposition - lecture. Examples	2 hours
Classical description of the electromagnetic field, plane wave, Gaussian modes	Systematic exposition - lecture. Examples	4 hours
Description of the electromagnetic field in quantum theory	Systematic exposition - lecture. Examples	4 hours
Free particle in electromagnetic field: classical / quantum description.	Systematic exposition - lecture. Examples	4 hours
Radiation interaction with atomic systems: amplitude / transition rate, effective sections.	Systematic exposition - lecture. Examples	4 hours
Multiphotonic processes, perturbative / non-perturbative description	Systematic exposition - lecture. Examples	2 hours
Radiation scattering (Rayleigh, Raman, Compton).	Systematic exposition - lecture. Examples	4 hours
Elements of quantum electrodynamics in intense fields	Systematic exposition - lecture. Examples	2 hours

Bibliography:

63. M. Dondera, V. Florescu. *Capitole de fizica atomica teoretica, Ed. UB, 2005.*
64. F.H.M. Faisal, *Theory of multiphotonic processes,* Plenum Press, 1987
65. C. J. Joachain, N. Kylstra, R. M. Potvliege, *Atoms in intense laser fields,* Cambridge University Press, 2012.

66. **W. Greiner, *Quantum Mechanics: Special Chapters*, Springer, 1998**		
8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Numerical / approximate solutions of the Maxwell equations	Lecture. Problem solving.	4 hours
Motion of electrically charged particle in electromagnetic field, approximate / numerical solutions	Lecture. Problem solving.	6 hours
Volkov solutions in non-relativistic quantum mechanics	Lecture. Problem solving.	8 hours
Radiation reaction	Lecture. Problem solving.	4 hours
Perturbative description of the interaction of radiation with simple systems	Lecture. Problem solving.	4 hours
Elements of Floquet theory	Lecture. Problem solving.	2 hours

Bibliography:

1. C. Cohen-Tannoudji, J. Dupont-Roc, G. Grynberg, *Atom-Photon Interactions*, Wiley-VCH Verlag, 2004.
2. J. D. Jackson Classical Electrodynamics (Wiley, 1962).
3. M. Boca, Lecture notes

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

The contents and teaching methods were selected after an analysis of the contents of similar course units in the syllabus of other universities (LMU, KTH) . The contents are in line with the requirements/expectations of the main employers of the graduates (research, academic, secondary school teaching).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyse specific examples	Written test/oral examination	50%
10.5.1. Tutorials	- ability to use specific problem solving methods	Homeworks/written tests	50%
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) Solving of all homework, Correct presentation of the subjects indicated for mark 5 in the final exam.			

Date 25.05.2019

Teacher's name and signature
Conf. dr. Madalina Boca

Practicals/Tutorials instructor(s) name(s) and signature(s)
Conf. dr. Madalina Boca

Date of approval
10.06.2019

Head of Department Prof.dr. Virgil Baran

DFC.210 Computational methods in modern physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Electricity, Solid State Physics and Biophysics
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	Physics of advanced materials and nanostructures
1.7. Study mode	Full-time study

2. Course unit

2.1. Course title	Computational methods in modern physics							
2.2. Teacher			Assoc. Prof. Alexandru Nicolin / Lect. Dr. Roxana Zus					
2.3. Tutorials instructor(s)								
2.4. Practicals instructor(s)			Dr. Mihai Marciu					
2.5. Year of study	2	2.6. Semester	1	2.7. Type of evaluation	E	2.8. Type of course unit	Content[1]	**DA**
							Type[2]	**DO**

[1] deepening (DA), speciality/fundamental (DS);
[2] compulsory (DI), elective (DO), optional (DFac)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	4	distribution: Lecture	2	Practicals/Tutorials	2
3.2. Total hours per semester	56	Lecture	28	Practicals/Tutorials	28

Distribution of estimated time for study	hours
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography	30
3.2.2. Research in library, study of electronic resources, field research	30
3.2.3. Preparation for practicals/tutorials/projects/reports/homework	30
3.2.4. Preparation for exam	4
3.2.5. Other activities	0

3.3. Total hours of individual study	90
3.4. Total hours per semester	150
3.5. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Programming languages, Linear algebra, Analytical mechanics, Electrodynamics, Quantum Mechanics,Thermodynamics and Statistical Physics
4.2. competences	Working with software packages which do not require a license for data analysis and data processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for practicals/tutorials	Scientific computing laboratory

6. Specific competences acquired

Professional competences	49. Understanding how to solve differential equations with Hamiltonian structure using the leapfrog method and related methods. Understanding time-reversibility and energy conservation. 50. Understanding finite difference methods and their use in numerical study of the Schrödinger equation. Understanding the conservation of the norm of the wave function and the emergence of numerical instabilities. 51. Understanding the use of finite difference methods for numerically solving Maxwell equations. 52. Understanding the dynamics of electrically charged particles moving in an electromagnetic through the numerical solution of the Vlasov equation using the test particle method. 53. Understanding *particle-in-cell* equations and self-consistent solution of field equations and those describing particle dynamics. Understanding the Boris algorithm for particle propagation over time and the Courant stability condition.
Transversal competences	**23.** Efficient use of scientific information resources and of communication and of resources for professional formation in English. **24.** Efficient and responsible implementation of professional tasks, with observance of the laws, ethics and deontology.

7. Course objectives

7.1. General objective	Presentation of computational methods in modern physics
7.2. Specific objectives	Study of leapfrog method and related methods for solving differential equations of Hamiltonian structure Study of finite-difference methods for solving the Schrödinger equation and Maxwell equations Study of the test particle method used to numerically solve the Vlasov equation Study of particle-in-cell equations that describe the dynamics of electrically charged particles in an electromagnetic field The study of the interaction of laser pulses with metal clusters

8. Contents

8.1. Lecture	Teaching techniques	Observations/ hours
Simplectic and near-simplectic methods for numerical solving of differential equations with Hamiltonian structure. Energy and volume conservation in the phase space.	Systematic exposition - lecture. Examples	2 hours
Finite-difference methods for the three-dimensional Schrödinger equation (especially for periodic and harmonic potential). Conservation of the norm. Stability conditions. Numerical instabilities. Border conditions. Analytical calculations for calibrating the accuracy of numerical schemes.	Systematic exposition - lecture. Examples	4 hours
Finite difference methods for Maxwell equations. Border conditions. Numerical instabilities.	Systematic exposition - lecture. Examples	6 hours
The Vlasov equation and the test particle method. Derivation of particle-in-cell equations. Study of shape functions.	Systematic exposition - lecture. Examples	4 hours
Self-consistent solving of field equations and those	Systematic exposition -	4 hours

describing particle dynamics. Boris algorithm for particle propagation over time. Courant stability condition.	lecture. Examples	
Interaction of laser pulses with metal clusters	Systematic exposition - lecture. Examples	4 hours
Comparative presentation of particle-in-cell codes available for solving equations.	Systematic exposition - lecture. Examples	4 hours

Bibliography:

38. B. Leimkuhler și S. Reich, *Simulating Hamiltonian dynamics*, Cambridge University Press, 2004.

39. D.F. Griffiths, J.W. Dold și D.J. Silvester, *Essential partial differential equations. Analytical and computational aspects,* Springer, 2015.

40. S. Mazumder, *Numerical methods for partial differential equations. Finite difference and finite volume methods*, Academic Press, 2016.

41. S.E. Koonin și D.C. Meredith, *Computational physics. Fortran versions*, Perseus Books, 1998.

42. P. Mulser și D. Bauer, *High power laser-matter interaction*, Springer, 2010.

43. P.G. Reinhard și E. Suraud, *Introduction to cluster dynamics*, Wiley-VCH, 2004.

44. K. Langanke, J.A. Maruhn și S.E. Koonin, Eds., *Computational Nuclear Physics 2. Nuclear Reactions*, Springer, 1993.

45. T.D. Arber *et al.*, *Contemporary particle-in-cell approach to laser-plasma modelling*, Plasma Phys. Control. Fusion **57**, 113001 (2015)

8.2. Tutorials	Teaching and learning techniques	Observations
Solving the three-dimensional Schrödinger equation for a harmonic (radial) and periodic (transverse) potential. Variational determination of the solution of the Schrödinger equation with cubic nonlinearities.	Lecture. Problem solving	4 hours
The analytical solution of Maxwell equations in a two- and three-dimensional numerical setup, in homogeneous environments.	Lecture. Problem solving	4 hours

Bibliography:

G.L. Squires, *Problems in quantum mechanics with solutions*, Cambridge University Press, 1995.

Y.-K. Lim, *Problems and solutions on electromagnetism*, World Scientific, 1993

8.3 Laboratory	Teaching and learning techniques	Observations
Numerical solution of differential equations with Hamiltonian structure by simplectic and quasi-simplectic methods. Code in Octave/python/C/C ++	Supervised practical activity	4 hours
The numerical solution of the Schrödinger equation. Code in Octave/python/C/C ++	Supervised practical activity	4 hours
Numerical solution of Maxwell equations. Code in Octave/python/C/C++	Supervised practical activity	4 hours
Numerical solution of particle-in-cell equations. Observation of ultra-intense laser pulse interaction with gaseous and solid targets, wakefield acceleration. Use of EPOCH PIC code	Supervised practical activity	6 hours
Numerical solution of the Vlasov equation. Use of existing FORTRAN programs	Supervised practical activity	2 hours

Bibliography:

67. B. Leimkuhler și S. Reich, *Simulating Hamiltonian dynamics*, Cambridge University Press, 2004.

68. K.W. Morton și D.F. Mayers, *Numerical solution of partial differential equations*, Cambridge University Press, 2005.

69. Yu.N. Grigoryev *et al.*, *Numerical particle-in-cell methods: Theory and applications*, de Gruyter,

2002.		
8.4 Project	Teaching and learning techniques	Observations
Bibliography:		

9. Compatibility of the course unit contents with the expectations of the representatives of epistemic communities, professional associations and employers (in the field of the study program)

In order to sketch the contents, to choose the teaching/learning methods, the coordinator of the course consulted the content of similar disciplines taught at Romanian universities and abroad. The content of the discipline is according to the requirements of employment in research institutes in physics and materials science, as well as in education (according to the law).

10. Assessment

Activity type	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in final mark
10.4. Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test/oral examination	60%
10.5.1. Tutorials	- Ability to use specific problem-solving methods	Homework	10%
10.5.2 Laboratory	- Ability to use specific problem-solving methods	Homework	30%
10.5.3 Project			
10.6. Minimal requirements for passing the exam			
Requirements for mark 5 (10 points scale) At least 50% of exam score and of homeworks.			

Date 10.06.2019	Teacher's name and signature Assoc. Prof. Alexandru Nicolin, Lect. Dr. Roxana Zus	Practicals/Tutorials instructor(s) name(s) and signature(s) Dr. Mihai Marciu,

Date of approval

Head of Department

Prof. Virgil Băran