Programul de studii: Theoretical and Computational Physics

Domeniul de studii: Fizică/Physics
Ciclul de studii: Master

Discipline obligatorii:

DI.101 Quantum Statistical Physics
DI.102 Group Theory and Applications in Physics
DI.103 Ethics and academic integrity
DI.107 Relativistic quantum mechanics and Quantum electrodynamics
DI.108 Theory of Nuclear systems and photonuclear reactions
DI.201 Introduction to quantum theory of fields
DI.207 Introduction to gravity theory and cosmology
DI.208 Research activity (traineeship – 180 hours)
DI.209 Finalization of master thesis (90 hours / 4 weeks)
DI.210 Public defense of master thesis

Discipline opţionale:

DO.104.1 Nonlinear dynamics, chaos,physics of complex systems
DO.104.2 Special chapters of Mathematics
DO.105.1 Artificial intelligence and machine learning in theoretical physics
DO.105.2 Simulation methods in theoretical physics
DO.109.1 Interaction of laser radiation with matter
DO.109.2 Quantum Optics
DO.110.1 Introduction to quantum theory of identical particles
DO.110.2 Theory of critical phenomena
DO.111.1 Quantum information and communication
DO.111.2 Collision theory
DO.202.1 Advanced methods in statistical physics
DO.202.2 Computational methods for electronic structures of condensed systems
DO.203.1 Computational methods in modern physics
DO.203.2 Theory of intense laser radiation interaction with atomic and nuclear systems
DO.204.1 Non-abelian gauge theories and standard model of elementary particles
DO.204.2 Theory of hadronic matter in extreme conditions and quark-gluon plasma

Discipline facultative:

DFC.106 Volunteering
DFC.112 Physics of mesoscopic systems
DFC.113 Advanced methods for parallel computing
DFC.114 Volunteering
DFC.115 Data science and computational electronic structure methods for soft-end bio-matter
DFC.205 Computational approaches in high-energy physics
DFC.206 Volunteering
DFC.211 Extensions of the standard model of elementary particles
DFC.212 Introduction to string theory
DFC.213 Volunteering

Syllabus

Academic year 2025/2026
DI.101 Quantum Statistical Physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

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. Virgil V. Baran						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	1/0/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	14/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					30
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					15
Tutorat					0
Other activities					58
3.7. Total hours of individual study					133
3.8. Total hours per semester					175
3.9. ECTS					7

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Classical Statistical Mechanics, Equations of Mathematical
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 tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems. R7. The student/graduate communicates effectively through scientific reports, presentations, and publications.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains. R7. Prepares clear scientific communication and documentation.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks. R7. Uses diverse information sources and digital tools responsibly.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
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.		4 Hours
Quantum liquids. Helium three. Helium four and Bose-Einstein condensation.		4 Hours

References:

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 and sons, 1987
4. Radu Paul Lungu, Elemente de mecanica statistica cuantica, Editura UB, 2017.

7.2 Tutorials	Teaching techniques	Observations
The statistical thermodynamics of the ideal fermionic gas. White dwarf stars. Neutron stars.	Problem solving	4 Hours
The statistical thermodynamics of the ideal bosonic gas.	Problem solving	4 Hours
Statistical mechanics of lattice vibrations. Phonons. Debye model.	Problem solving	2 Hours
Heisenberg model and applications.	Problem solving	4 Hours

References:

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

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50 of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. Dr. Virgil Baran	Lect. Dr. Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.102 Group Theory and Applications in Physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Group Theory and Applications in Physics
2.2. Teacher	Prof. Dr. Virgil Baran
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Cristian Iorga

2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	2	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	1/0/0
3.4. Total hours per semester	28	3.5. Lectures	14	3.6. Tutorials/Practicals/Projects	14/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	20
Research in library, study of electronic resources, field research	20
Preparation for practicals/tutorials/projects/reports/homework	25
Tutorat	0
Other activities	57
3.7. Total hours of individual study	122
3.8. Total hours per semester	150
3.9. 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 tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations

Introductory notions:symmetries of a physical system, the role of group theory in physics, groups clasification.	Systematic exposition - lecture. Examples	1 Hour
Group axioms, group multiplication table, subgroups, mappings of groups, direct product of groups.	Systematic exposition - lecture. Examples	1 Hour
Conjugate elements, equivalence classes, invariant subgroups, cosets, quotient group	Systematic exposition - lecture. Examples	2 Hours
Matrix representation of a group, equivalent representations, irreducible representation. Schur;s lemma.	Systematic exposition - lecture. Examples	2 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

References:
1. J.F. Corwell, Group theory in physics. An Introduction. Academic Press, 1997.
2. A. Zee, Group theory in a nutshell for physicist, Princeton University Press, 2017
3. W.K. Tung, Group theory in physics, World Scientific, 1985

7.2 Tutorials	**Teaching techniques**	**Observations**
Basic group theory. Aplications.	Problem solving	2 Hours
Discrete groups representations.	Problem solving	2 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

References:
1. A. Zee, Group theory in a nutshell for physicist, Princeton University Press, 2017
2. W.K. Tung, Group theory in physics: Problems and solutions, World Scientific, 1991
3. S. Sternberg, Group theory and physics, Cambridge University Press, 1994

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test/oral examination	60%
Tutorial	- Ability to use specific problem solving methods	Homeworks	40%

Minimal requirements for passing the exam	At least 50% of exam score.

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. Dr. Virgil Baran	Lect. Dr. Cristian Iorga

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.103 Ethics and academic integrity

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Matter Structure, Atmospheric and Earth Physics, Astrophysics
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Ethics and academic integrity						
2.2. Teacher	lector dr.Sanda Voinea						
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	1	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	0/0/0
3.4. Total hours per semester	14	3.5. Lectures	14	3.6. Tutorials/Practicals/Projects	0/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					31
Research in library, study of electronic resources, field research					15
Preparation for practicals/tutorials/projects/reports/homework					15
Tutorat					0
Other activities					0
3.7. Total hours of individual study					61
3.8. Total hours per semester					75
3.9. ECTS					3

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R8. The student/graduate applies ethical standards, assumes responsibility, and demonstrates autonomy in research.
Skills	R8. Applies good research practices and maintains academic integrity.
Responsibility and autonomy	R8. Shows autonomy, responsibility, and ethical awareness in professional activities.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Moral evaluation frameworks. Fundamental concepts of ethics. Ethics and the scientific community. Criteria for moral evaluation: consequences / intentions, virtues.	Lecture. Example. Discussion.	2 Hours

Academic integrity: institutional tools. Codes and ethics commissions.	Lecture. Example. Discussion.	2 Hours
Principles of research ethics	Lecture. Example. Discussion.	2 Hours
Challenges and dilemmas in research ethics	Lecture. Example. Discussion.	2 Hours
Publication ethics: authorship and co-authorship	Lecture. Example. Discussion.	2 Hours
Access to resources (fairness and equity in academic organizations and research teams)	Lecture. Example. Discussion.	2 Hours
Deontology of teamwork in scientific research	Lecture. Example. Discussion.	2 Hours

References:

Julian Baggini, Peter S. Fosl, A Compendium of Ethical Concepts and Methods, Blackwell Publishing, 2014.

Blaxter, L, Hugh, C. Tight, L. How to research, New York, 2006

Angelo Corlett. " The Role of Philosophy in Academic Ethics", Journal of Academic Ethics, Volume 12, Issue 1, pp 1–14, 2014

Codul de etică al Universităţii din Bucureşti https://unibuc.ro/wp-content/uploads/2021/01/CODUL-DE-ETICA-SI-DEONTOLOGIE-AL-UNIVERSITATII-DIN-BUCURESTI-2020-1.pdf

Carta UNIBUC (https://unibuc.ro/wp-content/uploads/2018/12/CARTA-UB.pdf)

Joshua D. Greene, et. al. "An fMRI investigation of emotional engagement in moral judgment." Science, 2001.

Neil Hamilton. Academic Ethics, Westport: Praeger Publishers, 2002

Bruce Macfarlane. Researching with Integrity. The Ethics of Academic Enquiry, London: Routledge, 2009.

James Rachels, Introducere în Etică, traducere de Daniela Angelescu, Editura Punct, 2000.

Ebony Elizabeth Thomas and Kelly Sassi, "An Ethical Dilemma: Talking about Plagiarism and Academic Integrity in the Digital Age", English Journal 100.6, pp. 47–53, 2011

Anthony Weston, A Practical Companion to Ethics, Oxford University Press, 2011

Barrow, R., Keeney, P. (eds), Academic Ethics, New York: Routledge, 2006

Bretag, T. (ed), Handbook of Academic Integrity, Singapore: Springer, 2016

8. 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 course addresses the most discussed theoretical issues in the area of academic ethics, along with their practical implications for impact. Not only abstract arguments and positions are discussed and evaluated, but also issues related to the ethical infrastructure of academic organizations or moral decision-making tools that can be used by students in their academic work and future professional life

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Minimal requirements for passing the exam	Achieving the grade of ADMISSION in the essay , attending at least 50% of the courses

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	lector dr.Sanda Voinea	

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Sanda VOINEA

Syllabus

Academic year 2025/2026
DI.107 Relativistic quantum mechanics and Quantum electrodynamics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Relativistic quantum mechanics and Quantum electrodynamics
2.2. Teacher	Conf. Madalina Boca
2.3. Tutorials/Practicals instructor(s)	Lector Virgil V. Baran

2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	40
Research in library, study of electronic resources, field research	30
Preparation for practicals/tutorials/projects/reports/homework	24
Tutorat	0
Other activities	0
3.7. Total hours of individual study	94
3.8. Total hours per semester	150
3.9. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum Mechanics, Electrodynamics and theory of relativity, Equations of mathematical physics
4.2. competences	Solving of problems in quantum mechanics, higher mathematics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Room with video projector, internet connection
5.2. for tutorials/practicals	Room with video projector, internet connection

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems. R9. The student/graduate contributes to teamwork and interdisciplinary projects, managing resources efficiently.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains. R9. Collaborates across disciplines and manages research workflows.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks. R9. Contributes actively to research teams and professional communities.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Dirac equation. Bispinors. Dirac matrices. The Pauli theorem. The relativistic invariance of Dirac equation.	Systematic exposition - lecture. Examples	4 Hours
Lorentz transformations; the transformation of the solutions of Dirac equation. Continuous transformations (rotations, special Lorentz transformations) and discrete transformations (spatial and temporal inversion)	Systematic exposition - lecture. Examples	4 Hours
Basic solutions of Dirac equation for the free particle. Plane waves. Positive and negative frequencies. Spin 1/2. Projection operators. The helicity.	Systematic exposition - lecture. Examples	4 Hours
Charge conjugation, Transformation of characteristic quantities to charge conjugation. The reinterpretation of the negative frequency states. The positron.	Systematic exposition - lecture. Examples	2 Hours
The scalar field, the Klein-Gordon equation; fundamental solutions, quantization of the real scalar field. Creation and annihilation operators. The covariant form of the commutation relations. The normal and chronological product	Systematic exposition - lecture. Examples	3 Hours
The electron-positron field. The Dirac Lagrange and Hamilton functions, The Dirac equation. Quantization of the electron-positron field. The electromagnetic interaction and the gauge invariance.	Systematic exposition - lecture. Examples	2 Hours
The electromagnetic field. The covariant form of the electromagnetism laws. The Lagrange function of the electromagnetic field. Quantization of the electromagnetic field. Gupta-Bleuler conditions.	Systematic exposition - lecture. Examples	2 Hours
Interacting fields. The interaction Hamiltonian în QED. The S matrix. Series expansion on the S matrix. Expansion of the S matrix. Wick theorem, Feynman diagrams and rules.	Systematic exposition - lecture. Examples	4 Hours
Cross sections, examples for fundamental processes	Systematic exposition - lecture. Examples	3 Hours

References:
1. M. Maggiore, A modern introduction to quantum field theory, Oxford University Press, 2008
2. L Maiani, O. Benhar, Relativistic Quantum Mechanics: An Introduction to Relativistic Quantum Fields, Taylor and Francis, 2024
3. U. Jentschura, G. Adkins, Quantum electrodynamics: atoms, lasers and gravity, World Scientific 2022
4. F. Schwabl, Advanced Quantum Mechanics, Springer Verlag, 2005
5. A. Wachter, Relativistic Quantum Mechanics, Springer, 2011
6. F. Mandl, G. Shaw, Quantum Field Theory, John Wiley and Sons, 2010
7. M. Peskin, D. Schroeder, An Introduction to Quantum Field Theory, Addison Wesley, 1996
8. W. Greiner, J. Reinhardt, Quantum Electrodynamics, Springer,2009
9. J.M. Jauch, F. Rohrlich, The Theory of Photons and Electrons, Springer Verlag, 1980
10. A.I. Akhiezer, V.B. Berestetskii, Quantum Electrodynamics, Interscience, 1965

7.2 Tutorials	**Teaching techniques**	**Observations**
Review of some elements of Group theory and theory of relativity	Lecture. Problem solving.	2 Hours
Properties of the Dirac matrices	Lecture. Problem solving.	2 Hours
Bilinear covariants of Dirac bispinors. Representations of Dirac matrices. Calculation of the traces.	Lecture. Problem solving.	2 Hours
Completeness and orthogonality of the plane waves solutions of the Dirac equation	Lecture. Problem solving.	2 Hours
Relativistic electron in constant magnetic field.	Lecture. Problem solving.	2 Hours
Solutions of the 1D Dirac equation	Lecture. Problem solving.	2 Hours
Complex scalar field and charge conservation	Lecture. Problem solving.	2 Hours
The Feynman propagator for the Klein Gordon and Dirac equations	Lecture. Problem solving.	6 Hours
The Feynman propagator for the electromagnetic field	Lecture. Problem solving.	2 Hours
Calculation of cross section for some fundamental processes	Lecture. Problem solving.	6 Hours

References:
1. M. Maggiore, A modern introduction to quantum field theory, Oxford University Press, 2008
2. L Maiani, O. Benhar, Relativistic Quantum Mechanics: An Introduction to Relativistic Quantum Fields, Taylor and Francis, 2024
3. U. Jentschura, G. Adkins, Quantum electrodynamics: atoms, lasers and gravity, World Scientific 2022
4. F. Schwabl, Advanced Quantum Mechanics, Springer Verlag, 2005
5. A. Wachter, Relativistic Quantum Mechanics, Springer, 2011
6. F. Mandl, G. Shaw, Quantum Field Theory, John Wiley and Sons, 2010
7. M. Peskin, D. Schroeder, An Introduction to Quantum Field Theory, Addison Wesley, 1996
8. W. Greiner, J. Reinhardt, Quantum Electrodynamics, Springer,2009
9. J.M. Jauch, F. Rohrlich, The Theory of Photons and Electrons, Springer Verlag, 1980
10. A.I. Akhiezer, V.B. Berestetskii, Quantum Electrodynamics, Interscience, 1965

8. 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 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/expectations of the main employers of the graduates (industry, research, academic, secondary school teaching).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	Clarity and coherence of exposition Correct use of the methods/ physical models The ability to give specific examples		70%

Tutorial	Ability to use specific problem solving methods		30%

Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale): - At least 50% of exam score and of homework. Requirements for mark 10 (10 points scale): - At least 95% of exam score and of homework.

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. Madalina Boca	Lector Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.108 Theory of Nuclear systems and photonuclear reactions

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Theory of Nuclear systems and photonuclear reactions						
2.2. Teacher	Lect. Dr. Virgil V. Baran						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Virgil V. Baran						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	1/0/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	14/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					25
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					35
Tutorat					0
Other activities					18
3.7. Total hours of individual study					108
3.8. Total hours per semester					150
3.9. 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 tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems. R7. The student/graduate communicates effectively through scientific reports, presentations, and publications.

Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains. R7. Prepares clear scientific communication and documentation.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks. R7. Uses diverse information sources and digital tools responsibly.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Fundamental properties of nucleon-nucleon interaction. The origin of nuclear interactions, properties of the nuclear forces as derived from experimental observations. The nuclear matter, saturation properties. Observables of interest in nuclear physics	Systematic exposition - lecture. Examples	4 Hours
Phenomenological nuclear models: Bohr-Mottelson model, interacting bosons models.	Systematic exposition - lecture. Examples	6 Hours
Microscopic nuclear models: shell model and its extensions.	Systematic exposition - lecture. Examples	4 Hours
Many-body methods for describing the quantum states of nuclear systems: Hartree-Fock , Bardeen-Cooper -Schrieffer, Time-dependent Hartree-Fock, Random-Phase Approximation	Systematic exposition - lecture. Examples	6 Hours
Electromagnetic transitions in nuclear physics: the interaction between electromagnetic field and nucleus. Multipole electromagnetic transitions, reduced transition probabilities. One particle matrix elements in a spherical basis set, Weisskopf units. The giant dipole resonance and the cross section of absorption of dipole radiation. Sum- rules. Collective excitations in atomic nuclei.	Systematic exposition - lecture. Examples	4 Hours
Fundamentals of nuclear astrophysics: supernova explosion, properties of neutron stars, stellar nucleosynthesis, elements abundance. Theoretical basis of nuclear astronomy and cosmology.	Systematic exposition - lecture. Examples	4 Hours

References:

1. J.L. Basdevant, J Rich, M. Spiro, Fundamentals in nuclear physics, Springer, 2005.
2. W. Greiner, J.A. Maruhn, Nuclear Models, Springer, 1996.
3. P.Ring and P. Schuck, Nuclear many body problem, Springer, 2004.

7.2 Tutorials	**Teaching techniques**	**Observations**
Fermi gas model for nuclear matter.	Problem solving	1 Hour
Pauli quantization for quadrupole degrees of freedom. Collective states of a deformed nucleus. Group theoretical methods for low-lying states.	Problem solving	3 Hours
Single particle properties in various potential wells for nuclear systems.	Problem solving	1 Hour
Many-body calculations of nuclear properties.	Problem solving	4 Hours

Photonuclear reaction. Electromagnetic transitions.	Problem solving	3 Hours
Properties of neutrons stars. Supernova explosions.	Problem solving	2 Hours

References:

1. P.A. Martin, F. Rothen, Many-body problems and quantum field theory, Springer, 2002
2. J.Eisenberg and W. Greiner, Nuclear models, vol. 1,2, 3

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Virgil V. Baran	Lect. Dr. Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.201 Introduction to quantum theory of fields

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Introduction to quantum theory of fields
2.2. Teacher	Lect. dr. Roxana Zus
2.3. Tutorials/Practicals instructor(s)	Lect. dr. Stefan-Alexandru Ghinescu

2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	25
Research in library, study of electronic resources, field research	30
Preparation for practicals/tutorials/projects/reports/homework	35
Tutorat	0
Other activities	54
3.7. Total hours of individual study	144
3.8. Total hours per semester	200
3.9. ECTS	8

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Electrodynamics, Theory of relativity
4.2. competences	Knowledge about: mechanics, algebra, solving differential equations

5. Conditions/Infrastructure (if necessary)

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

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Fundamental properties of elementary particles. Relevant experimental facts. Orders of magnitude in elementary particle physics, dimensional analysis.	Systematic exposition - lecture. Examples	2 Hours
The Lorentz (LG) and Poincare (PG) groups: definition and basic properties. Generators and Lie algebra of the Lorentz and Poincare groups. Finite irreducible representations of LG and classification of classical fields. Scalar, vectorial, spinorial fields.	Systematic exposition - lecture. Examples	4 Hours
Variational principle for classical fields and Noether theorem. Dynamical invariants.	Systematic exposition - lecture. Examples	2 Hours
Free fields: Klein-Gordon field, Weyl field, Dirac field, Majorana field, Maxwell field, Proca Field. Frequency decomposition of the fields. Spin and charge.	Systematic exposition - lecture. Examples	8 Hours
Quantization of the fundamental fields, elementary particles, commutation relations, spin-statistics theorem.	Systematic exposition - lecture. Examples	4 Hours
Local gauge invariance and interaction. Spontaneous breaking of symmetries. Goldstone model. Higgs mechanism.	Systematic exposition - lecture. Examples	4 Hours
Interacting quantum fields. Feynman diagrams. Fundamentals of renormalization	Systematic exposition - lecture. Examples	4 Hours

References:

1. M. Maggiore, A modern introduction to Quantum Field Theory, Oxford University Press, 2005.
2. T. Morii, C. S. Lim, S. N. Mukherjee, The Physics of the Standard Model and Beyond, World Scientific, 2004.
3. David Tong, Lectures on Quantum Field Theory, University of Cambridge, 2007, https://www.damtp.cam.ac.uk/user/tong/qft.html
4. M.E. Peskin, D.V. Schroeder An Introduction to Quantum Field Theory, Advanced Book Program, Addison-Wesley Publishing Company, 1995.
5. N.N. Bogoliubov, D.V. Shirkov, Introduction to The Theory of Quantized Fields, John Wiley and Sons, 1980
6. S. Weinberg, The quantum theory of fields, Vol. I and Vol. II Cambridge University Press, 2005.
7. V.B. Berestetskii, E.M. Lifshitz , L.P. Pitaevskii , Quantum Electrodynamics, Perg. Press, 1989.
8. T.D. Lee, Particle Physics and Introduction to Field Theory, Hardwood Academic, 1981.
9. A. Zee, Quantum Field Theory in a Nutshell, Princeton University Press,2003."
10. R. D. Klauber, Student Friendly Quantum Field Theory: Volume 1: Basic Principles and Quantum Electrodynamics, 2nd edition, Sandtrove Press, 2013
11. R. D. Klauber, Student Friendly Quantum Field Theory: Volume 2: The Standard Model, 2nd edition, Sandtrove Press, 2021

7.2 Tutorials	Teaching techniques	Observations
Lorentz Group algebra. Poincare group algebra. Pauli-Lubansky four-vectors. Casimir operators.	Problem solving	4 Hours
Dynamical invariants for classical fields. Frequency decompositions.	Problem solving	4 Hours
Commutation functions for free fields. Causality.	Problem solving	3 Hours

Discrete symmetries of physical fields.	Problem solving	3 Hours
Models for spontaneous global symmetry breaking. Goldstone theorem.	Problem solving	4 Hours
Models for Higgs mechanism.	Problem solving	4 Hours
Perturbative methods for interacting quantum fields. Renormalization.	Problem solving	6 Hours

References:
1. Voja Radovanovich, Problem book in quantum field theory, Springer, 2005
2. C. Itzykson and J.B. Zuber, Quantum Field Theory, McGraw-Hill, New York, 1980
3. M. Kaku, Quantum Field Theory: A Modern Introduction, Oxford University Press, 1993
4. F. Mandl and G. Shaw, Quantum Field Theory, New York, 1999

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Practical	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale): - At least 50% of exam score and of homework. Requirements for mark 10 (10 points scale): - At least 95% of exam score and of homework.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. dr. Roxana Zus	Lect. dr. Stefan-Alexandru Ghinescu

Date of approval

15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.207 Introduction to gravity theory and cosmology

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Introduction to gravity theory and cosmology						
2.2. Teacher	R. Slobodeanu						
2.3. Tutorials/Practicals instructor(s)	M. Marciu						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	1/0/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	14/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					42
Research in library, study of electronic resources, field research					21
Preparation for practicals/tutorials/projects/reports/homework					20
Tutorat					0
Other activities					0
3.7. Total hours of individual study					83
3.8. Total hours per semester					125
3.9. ECTS					5

4. Prerequisites (if necessary)

4.1. curriculum	Real and Complex Analysis, Algebra, Differential Equations, Equations of Mathematical Physics, Classical Mechanics, Special Relativity
4.2. competences	Computational skills in differential and integral calculus, partial differential equations, special functions. Familiarity with the formalism of classical mechanics; the principle of least action;

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.

Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
The principles of special relativity and the Minkowski space	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Manifolds and differential forms	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Curvature, parallel transport and covariant derivatives, geodesic equations	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Einstein's equations and the variational formulation of general relativity. Scalar fields in curved space-time	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Spherically symmetric solutions (Schwarzschild spacetime, black holes and neutron stars)	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Gravitational waves	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Elements of modern cosmology: the dark energy and dark matter problems	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
References: dffd		
7.2 Tutorials	**Teaching techniques**	**Observations**
Geometry in a 4-dimensional space-time: vectors, dual vectors and tensors. Basic properties of the Lorentz transformations. Description of the Lorentz and Poincare groups. Einstein's equivalence principle.	Problem solving. Guided work. Case study. Examples	2 Hours
The space-time metric; the Levi-Civita connection; derivation of the geodesic equations. The Riemann curvature tensor and the non-commutativity property of the covariant derivatives.	Problem solving. Guided work. Case study. Examples	2 Hours

Properties of the Riemann curvature tensor: the Bianchi identity. The Ricci, Weyl and Einstein tensors. Symmetries and Killing vectors for a specific metric. Applications.	Problem solving. Guided work. Case study. Examples	2 Hours
Einstein-Hilbert action and the principle of least action. Applications.	Problem solving. Guided work. Case study. Examples	2 Hours
Linearization of the Einstein's field equations. The gravitational wave equation. Plane wave solutions. Applications.	Problem solving. Guided work. Case study. Examples	2 Hours
Tolman-Oppenheimer-Volkoff equations. Applications.	Problem solving. Guided work. Case study. Examples	2 Hours
The Friedmann's equations. Applications. Derivation of the Klein-Gordon equations for scalar fields in curved space-time. The modified Friedmann relations	Problem solving. Guided work. Case study. Examples	2 Hours

References:

1. M. Blennow, T. Ohlsson, 300 Problems in Special and General Relativity, Cambridge University Press 2021.
2. C. G. Bohmer, Introduction to General Relativity and Cosmology, World Scientific, 2016
3. S. Nojiri, S.D. Odintsov, V.K. Oikonomou, Modified gravity theories on a nutshell: Inflation, bounce and late-time evolution, Physics Reports 692 (2017)
4. T. Padmanabhan, Cosmology and astrophysics through problems, Cambridge University press, 1996

8. 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 and abilities which are fundamental for a graduate student in the field of theoretical physics, corresponding to national and european/international standards. 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, the European Union, or the United States of America. The contents are in line with the requirements/expectations of the main employers of the graduates (industry, research, academic, secondary school teaching).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- coherence and clarity of exposition - correct use of equations, mathematical methods, physical models and theories - ability to indicate and analyse specific examples	oral presentation	50%
Tutorial	ability to use specific problem solving methods. Ability to analyse the results	Homeworks. Seminar activity	30%
Practical	ability to use Wolfram mathematica for computing various geometric tensors	Project assignement	20%
Minimal requirements for passing the exam	At least 50% of exam score and 50% of total score.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	R. Slobodeanu	M. Marciu

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.208 Research activity (traineeship – 180 hours)

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Research activity (traineeship – 180 hours)						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	8	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/8/0
3.4. Total hours per semester	80	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/80/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					210
Research in library, study of electronic resources, field research					105
Preparation for practicals/tutorials/projects/reports/homework					105
Tutorat					0
Other activities					0
3.7. Total hours of individual study					420
3.8. Total hours per semester					500
3.9. ECTS					20

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems. R7. The student/graduate communicates effectively through scientific reports, presentations, and publications. R8. The student/graduate applies ethical standards, assumes responsibility, and demonstrates autonomy in research. R9. The student/graduate contributes to teamwork and interdisciplinary projects, managing resources efficiently.
Skills	R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains. R7. Prepares clear scientific communication and documentation. R8. Applies good research practices and maintains academic integrity. R9. Collaborates across disciplines and manages research workflows.

Responsibility and autonomy	R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks. R7. Uses diverse information sources and digital tools responsibly. R8. Shows autonomy, responsibility, and ethical awareness in professional activities. R9. Contributes actively to research teams and professional communities.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam			

Date, 13.07.2025	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
Date of approval 15.07.2025		Head of department name and signature Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.209 Finalization of master thesis (90 hours / 4 weeks)

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title			Finalization of master thesis (90 hours / 4 weeks)				
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/4/0
3.4. Total hours per semester	40	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/40/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					43
Research in library, study of electronic resources, field research					21
Preparation for practicals/tutorials/projects/reports/homework					21
Tutorat					0
Other activities					0
3.7. Total hours of individual study					85
3.8. Total hours per semester					125
3.9. ECTS					5

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R7. The student/graduate communicates effectively through scientific reports, presentations, and publications. R8. The student/graduate applies ethical standards, assumes responsibility, and demonstrates autonomy in research. R9. The student/graduate contributes to teamwork and interdisciplinary projects, managing resources efficiently.
Skills	R5. Evaluates scientific literature and data with critical judgment. R7. Prepares clear scientific communication and documentation. R8. Applies good research practices and maintains academic integrity. R9. Collaborates across disciplines and manages research workflows.

Responsibility and autonomy	R5. Performs independent investigations with critical awareness. R7. Uses diverse information sources and digital tools responsibly. R8. Shows autonomy, responsibility, and ethical awareness in professional activities. R9. Contributes actively to research teams and professional communities.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam			

Date, 13.07.2025	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
Date of approval 15.07.2025		Head of department name and signature Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DI.210 Public defense of master thesis

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Public defense of master thesis
2.2. Teacher	
2.3. Tutorials/Practicals instructor(s)	

2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	0	2.7.Classification	

3. Total estimated time

3.1. Hours per week	0	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/0/0
3.4. Total hours per semester	0	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	125
Research in library, study of electronic resources, field research	63
Preparation for practicals/tutorials/projects/reports/homework	62
Tutorat	0
Other activities	0
3.7. Total hours of individual study	250
3.8. Total hours per semester	250
3.9. ECTS	10

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R7. The student/graduate communicates effectively through scientific reports, presentations, and publications. R8. The student/graduate applies ethical standards, assumes responsibility, and demonstrates autonomy in research. R9. The student/graduate contributes to teamwork and interdisciplinary projects, managing resources efficiently.
Skills	R7. Prepares clear scientific communication and documentation. R8. Applies good research practices and maintains academic integrity. R9. Collaborates across disciplines and manages research workflows.
Responsibility and autonomy	R7. Uses diverse information sources and digital tools responsibly. R8. Shows autonomy, responsibility, and ethical awareness in professional activities. R9. Contributes actively to research teams and professional communities.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam			

Date, 13.07.2025

Teacher's name and signature,

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

Date of approval 15.07.2025

Head of department name and signature Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026

DO.104.1 Nonlinear dynamics, chaos,physics of complex systems

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Nonlinear dynamics, chaos,physics of complex systems						
2.2. Teacher	Prof. Dr. Virgil Baran						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Virgil V. Baran						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0
Distribution of estimated time for study					
Learning by using one’s own course notes, manuals, lecture notes, bibliography					30
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					30
Tutorat					0
Other activities					29
3.7. Total hours of individual study					119
3.8. Total hours per semester					175
3.9. ECTS					7

4. Prerequisites (if necessary)

4.1. curriculum	Analytical 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 tutorials/practicals	Scientific computing laboratory

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Fluid dynamics and turbulence. Historical framework and physico-mathematical foundations.	Systematic exposition - lecture. Examples	2 Hours
The emergence of turbulence and the theory of dynamic systems. Presentation of the logistics application. Period doubling and the road to chaos. Lyapunov exponent for discrete systems. Feigenbaum numbers. Presentation of the tent and Henon maps.	Systematic exposition - lecture. Examples	4 Hours
Presentation of Navier-Stokes equations and shell models (especially Gledzer-Ohkitani-Yamada). Lyapunov exponent for continuous systems. The study of energy conservation and helicity.	Systematic exposition - lecture. Examples	6 Hours
Presentation of Lorenz equations. Sensitivity to initial conditions. Strange attractors. The Rössler system.	Systematic exposition - lecture. Examples	4 Hours
Presentation of Runge-Kutta numerical methods (explicit and implicit). Volume conservation in phase space.	Systematic exposition - lecture. Examples	4 Hours
Presentation of the sandpile model. Self-organized criticality. Fractal distributions. Applications in economics, sociology, astrophysics.	Systematic exposition - lecture. Examples	4 Hours
Presentation of complex networks, especially topology, dynamics, and universality. Basic principles of economics.	Systematic exposition - lecture. Examples	4 Hours

References:

1. S.H. Strogatz, Nonlinear dynamics and chaos. With applications to physics, biology, and engineering, CRC Press, 2015.
2. M. Tabor, Chaos and integrability in nonlinear dynamics. An introduction, Wiley, 1989.
3. T. Bohr, M.H. Jensen, G. Paladin şi A. Vulpiani, Dynamical systems approach to turbulence, Cambridge University Press, 2005.
4. M. Aschwanden, Self-organized criticality in astrophysics. The statistics of nonlinear processes in universe, Springer, 2011.
5. S. Lynch, Dynamical systems with applications with Python, Birkhauser, 2018.
6. R. Hilborn, Chaos and nonlinear dynamics. An introduction for scientists and engineers, Oxford University Press, 2001.
7. P. Bak, How nature works. The science of self-organized criticality, Copernicus, 1999.
8. A.L. Barabasi, Network science, Cambridge University Press, 2016.
9. R.N. Mantegna şi H.E. Stanley, An introduction to econophysics. Correlations and complexity in finance, Cambridge University Press, 2007.

7.2 Tutorials	**Teaching techniques**	**Observations**
Computing Reynolds numbers.	Lecture. Problem solving	2 Hours
Deriving shell-like equations from the Navier-Stokes equation.	Lecture. Problem solving	2 Hours
Determination of the two Feigenbaum constants in the numerical study of the Henon application	Supervised practical activity	2 Hours

Numerical solution of Lorenz equations. Runge-Kutta methods. Numerical algorithms for the Lyapunov exponent.	Supervised practical activity	6 Hours
Numerical solution of equations that describe shell models. The Kolmogorov spectrum	Supervised practical activity	6 Hours
Numerical study of the sandpile model and the Bak-Sneppen macroevolution model. Fractal distributions. Self-organized criticality.	Supervised practical activity	6 Hours
The study of complex networks. The model of preferential attachment. Distributions of words in Romanian.	Supervised practical activity	2 Hours
Financial markets. Hurst exponent calculation for time series describing the evolution of the exchange rate of currencies. Solving the Black-Scholes equation.	Supervised practical activity	2 Hours

References:

1. T. Bohr, M.H. Jensen, G. Paladin şi A. Vulpiani, Dynamical systems approach to turbulence, Cambridge University Press, 2005.
2. L. Biferale, Shell models of energy cascade in turbulence, Annual Review in Fluid Mechanics 35, 441 (2003).

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test/oral examination	60%
Tutorial	Ability to use specific problem-solving methods	Homework, Colloquium	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. Dr. Virgil Baran	Lect. Dr. Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.104.2 Special chapters of Mathematics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Special chapters of Mathematics						
2.2. Teacher	Assoc.prof. dr. Radu Slobodeanu						
2.3. Tutorials/Practicals instructor(s)	Lecturer dr. Adrian Stoica						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					60
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					29
Tutorat					0
Other activities					0
3.7. Total hours of individual study					119
3.8. Total hours per semester					175
3.9. ECTS					7

4. Prerequisites (if necessary)

4.1. curriculum	Algebra, Analysis, Quantum mechanics
4.2. competences	Knowledge about: mechanics, solving differential equations

5. Conditions/Infrastructure (if necessary)

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

6. Learning outcomes

Knowledge	R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools.
Skills	R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software.
Responsibility and autonomy	R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations

Differentiable manifolds. Tangent spaces. Vector fields. Differential forms.	Systematic exposition - lecture. Examples	6 Hours
Lie groups and Lie algebra.	Systematic exposition - lecture. Examples	8 Hours
Fibre bundles. Applications	Systematic exposition - lecture. Examples	6 Hours
Connection in a bundle. Parallel transport. Curvature.	Systematic exposition - lecture. Examples	8 Hours
References: C.J.Isham, Modern Differential Geometry for Physicists, World Scientific, 2001		
7.2 Tutorials	**Teaching techniques**	**Observations**
Fourier transform. Convolution product and its Fourier transform. Fourier transform of generalized functions. Dirac's distribution.	Problem solving	6 Hours
Complex functions: derivatives and contour integrals.	Problem solving	6 Hours
Taylor and Laurent series. Residues. Examples. Calculus of definite integrals by using residue theorem	Problem solving	4 Hours
Tensor calculus. Tensor products.	Problem solving	4 Hours
Orthogonal polynomials and special functions. Hypergeometric polynomials. Legendre's polynomials and associated functions. Laguerre's polynomials. Hermite's polynomials	Problem solving	4 Hours
Frames and orthonormal bases. The resolution of identity. Systems of coherent states. Quantification based on systems of coherent states or frames.	Problem solving	4 Hours
References: G. Teschl, Mathematical Methods in Quantum Mechanics with Applications to Schrodinger Operators, AMS 2009 M. Stone and P. Goldbart, Mathematics for Physicists, Cambridge University Press 2009		

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Assoc.prof. dr. Radu Slobodeanu	Lecturer dr. Adrian Stoica

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.105.1 Artificial intelligence and machine learning in theoretical physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Artificial intelligence and machine learning in theoretical physics						
2.2. Teacher	Lect. dr. Mihai Marciu						
2.3. Tutorials/Practicals instructor(s)	Lect. dr. Mihai Marciu						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DC

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/28/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					60
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					29
Tutorat					0
Other activities					0
3.7. Total hours of individual study					119
3.8. Total hours per semester					175
3.9. ECTS					7

4. Prerequisites (if necessary)

4.1. curriculum	Parcurgerea cursurilor: Programarea calculatoarelor I (C/C++); Limba engleză pentru ştiinţe;
4.2. competences	Abilitati de Fizică Computaţională

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Sală cu dotări multimedia (videoproiector)
5.2. for tutorials/practicals	Sală de laborator cu infrastructură specifică

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Introducere in Python. Gramatica limbajului Python. Instructiuni generale. Tipurile principale de date ale limbajului Python.	Expunere sistematica – prelegere. Exemple.	2 Hours
Tratarea exceptiilor in Python. Ierarhizarea exceptiilor. Programarea functionala in Python. Implementarea expresiilor regulate in Python.	Expunere sistematica – prelegere. Exemple.	2 Hours
Concepte fundamentale in programarea orientata pe obiecte. Notiunea de obiect si de clasa. Aplicatii in Python.	Expunere sistematica – prelegere. Exemple.	2 Hours
Introducere in programarea orientata pe obiecte in limbajul Python.	Expunere sistematica – prelegere. Exemple.	2 Hours
Implementarea claselor in Python. Mostenirea obiectelor. Polimorfism.	Expunere sistematica – prelegere. Exemple.	2 Hours
Definitia operatorilor. Serializarea obiectelor in Python. Iteratori.	Expunere sistematica – prelegere. Exemple.	4 Hours
Utilizarea bazelor de date (SQL/NoSQL) in Python. Aplicatii practice.	Expunere sistematica – prelegere. Exemple.	4 Hours
Programarea paralela in Python. Sincronizarea firelor de executie. Sisteme multi-procesor.	Expunere sistematica – prelegere. Exemple.	6 Hours
Elemente de networking in Python. Utilizarea protocoalelor FTP si HTTP.	Expunere sistematica – prelegere. Exemple.	2 Hours
Machine learning in Python. Prezentarea unor algoritmi specifici utilizati in procesarea informatiilor.	Expunere sistematica – prelegere. Exemple.	2 Hours

References:
Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems 2nd Edition

7.3 Practicals	**Teaching techniques**	**Observations**
Scrierea programelor iterative in Python. Aplicatii numerice.	Activitate practică dirijată	2 Hours
Utilizarea listelor in Python. Tratarea exceptiilor. Aplicatii numerice.	Activitate practică dirijată	2 Hours
Utilizarea claselor in Python. Aplicatii numerice.	Activitate practică dirijată	2 Hours
Mostenirea obiectelor si polimorfism. Aplicatii numerice.	Activitate practică dirijată	2 Hours
Rezolvarea ecuatiilor si a sistemelor de ecuatii algebrice. utilizand Python. Aplicatii numerice.	Activitate practică dirijată	2 Hours
Derivarea numerica a functiilor utilizand Python. Aplicatii numerice.	Activitate practică dirijată	4 Hours
Derivarea si integrarea numerica a functiilor utilizand Python. Aplicatii numerice.	Activitate practică dirijată	4 Hours
Rezolvarea ecuatiilor si a sistemelor de ecuatii diferentiale ordinare in Python. Aplicatii numerice.	Activitate practică dirijată	4 Hours
Rezolvarea ecuatiilor cu derivate partiale si integrale in Python. Aplicatii numerice.	Activitate practică dirijată	4 Hours
Machine learning in Python. Aplicatii numerice folosind biblioteca SciPy.	Activitate practică dirijată	2 Hours

References:
Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems 2nd Edition

8. 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

În vederea schiţării conţinuturilor, alegerii metodelor de predare/învăţare titularii disciplinei au consultat conţinutul unor discipline similare predate la universităţi din ţară şi străinătate. Conţinutul este în acord cu cerinţele Universităţii din Bucureşti şi cele la nivel naţional şi internaţional pentru redactarea şi prezentarea lucrărilor ştiinţifice.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam	Finalizarea tuturor lucrărilor de laborator şi nota 5 la colocviu. Expunerea corecta a subiectelor indicate pentru obţinerea punctajului 5 la examenul final.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. dr. Mihai Marciu	Lect. dr. Mihai Marciu

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.105.2 Simulation methods in theoretical physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title			Simulation methods in theoretical physics				
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/28/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					60
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					29
Tutorat					0
Other activities					0
3.7. Total hours of individual study					119
3.8. Total hours per semester					175
3.9. ECTS					7

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Presentation of Monte-Carlo methods, in particular the Ising model and the simulated annealing computational processes. Calculation of multidimensional integrals by Monte-Carlo methods.	Systematic exposition - lecture. Examples	6 Hours
Monte-Carlo quantum algorithms (variational, diffusive and integral path type). Quantum dots. He clusters on graphite surfaces	Systematic exposition - lecture. Examples	6 Hours
Presentation of the fundamental aspects regarding genetic algorithms and their use in the study of physical systems	Systematic exposition - lecture. Examples	4 Hours
Presentation of the implicit Runge-Kutta methods, with emphasis on symplecticness, volume conservation in phase space and numerical rigidity. Presentation of Gaussian quadratures. Case study: differential equations of Hamiltonian structure.	Systematic exposition - lecture. Examples	4 Hours
Presentation of integral transformations, in particular Laplace transformations, and their use in the numerical treatment of integral equations	Systematic exposition - lecture. Examples	4 Hours
Presentation of discrete models that describe the occurrence of earthquakes. Presentation of self-organized criticality and fractal distributions	Systematic exposition - lecture. Examples	4 Hours

References:

1. D.P. Landau şi K. Binder, A guide to Monte Carlo simulations in statistical physics, Cambridge University Press, 2014.
2. J.B. Anderson, Quantum Monte Carlo. Origins, development, applications, Oxford University Press, 2007.
3. T. Pang, An introduction to Quantum Monte Carlo methods, Morgan and Claypool Publishers, 2016.
4. D.A. Coley, An introduction to genetic algorithms for scientists and engineers, World Scientific, 1999.
5. J.C. Butcher, Numerical Methods for Ordinary Differential Equations, Wiley, 2016.
6. D. Porter şi D.S.G. Stirling, Integral equations: from spectral theory to applications, Cambridge University Press, 1991.

7.3 Practicals	**Teaching techniques**	**Observations**
Determination of critical temperature in high dimensional Ising systems using Monte-Carlo methods. Code in Octave/python/C/C++	Supervised practical activity	2 Hours
Calculation of Ising integrals using Monte-Carlo methods. Code in Octave/python/C/C++	Supervised practical activity	2 Hours
Numerical studies on quantum dots using quantum Monte-Carlo algorithms. Code in Octave/python/C/C++	Supervised practical activity	3 Hours
Determination of the fundamental state energy for a spin glass using genetic algorithms	Supervised practical activity	3 Hours

Numerical solution of non-linear oscillator equations by implicit Runge-Kutta methods. Energy conservation. Code in Octave/python/C/C++	Supervised practical activity	4 Hours
Determination of the volumes in the space of the phases populated by the regular and chaotic trajectories for a non-linear system with four dimensions. Code in Octave/python/C/C ++	Supervised practical activity	3 Hours
Solving Volterra-type integral equations by means of Laplace transforms. Code in Octave/python/C/C++	Supervised practical activity	3 Hours
Numerical resolution of the Olami-Feder-Christensen seismic model. Code in Octave/python/C/C++	Supervised practical activity	2 Hours
Determining the distribution of earthquake waiting times. Code in Octave/python/C/C ++	Supervised practical activity	2 Hours
One- and two-dimensional Ising systems	Problem solving	2 Hours
Analytic solutions of the equations which describe implicit Runge-Kutta methods using Gaussian quadratures	Problem solving	2 Hours

References:

1. D.P. Landau şi K. Binder, A guide to Monte Carlo simulations in statistical physics, Cambridge University Press, 2014.
2. T. Pang, An introduction to Quantum Monte Carlo methods, Morgan and Claypool Publishers, 2016.
3. D.A. Coley, An introduction to genetic algorithms for scientists and engineers, World Scientific, 1999.
4. E. Hairer et al., Geometric numerical integration: Structure-preserving algorithms for ordinary differential equations, Springer, 2002
5. B.M. McCoy şi T.T. Wu, The two-dimensional Ising model, Harvard University Press, 1973.

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	Written test/oral examination	60%
Tutorial	- Ability to use specific problem-solving methods	Homework	10%
Practical	- Ability to use specific problem-solving methods	Homework	30%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025		

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.109.1 Interaction of laser radiation with matter

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Interaction of laser radiation with matter
2.2. Teacher	Conf. Madalina Boca
2.3. Tutorials/Practicals instructor(s)	Conf. Madalina Boca

2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	2	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	28	3.5. Lectures	14	3.6. Tutorials/Practicals/Projects	0/14/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	61
Research in library, study of electronic resources, field research	31
Preparation for practicals/tutorials/projects/reports/homework	30
Tutorat	0
Other activities	0
3.7. Total hours of individual study	122
3.8. Total hours per semester	150
3.9. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Classical electrodynamics, Quantum Mechanics, Numerical methods in Physics
4.2. competences	Knowledge of basic topics in classical electrodynamics and quantum mechanics, ability to understand basic numerical algorithms

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Room with videoprojector, acces to internet
5.2. for tutorials/practicals	Computer room with videoprojector, acces to internet

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
1. Theoretical description of laser beams; particular solutions of the Maxwell equations: plane waves, Gaussian beams, helical beams.	Systematic exposition - lecture. Examples	4 Hours
2. Classical motion of the charged particle in the presence of a laser field; relativistic vs non relativist approach, radiation reaction effects, the Abraham-Lorentz force	Systematic exposition - lecture. Examples	4 Hours
3. Classical description of radiation scattering: linear and non-linear Thomson scattering, the energy spectrum and the angular momentum of the emitted field	Systematic exposition - lecture. Examples	4 Hours
4. Coherent non-linear Thomson scattering	Systematic exposition - lecture. Examples	2 Hours

References:

J. D. Jackson, Classical electrodynamics, John Wiley and Sons, 1999

C. Joachain, A. Kylstra, R. M. Potvliege, Atoms in intense laser fields, Cambridge University Press, 2012

A. Di Piazza, C. Muller, K. Z. Hatsagortsyan, and C. H. Keitel, Extremely high-intensity laser interactions with fundamental quantum systems, Rev. Mod. Phys. 84, 1177 (2012)

A. Gonoskov et al, Charged particle motion and radiation in strong electromagnetic fields, REv. Mod. Phys. 94, 045001, 2022

D. Suter, The Physics of Laser-Atom Interactions (Cambridge Studies in Modern Optics), 1997

F. V. Hartemann, High-field electrodynamics, CRC press, 2002

J. P. Torres (ed), Twisted photons: applications of light with orbital angular momentum, Wiley-VCH (2011)

7.3 Practicals	Teaching techniques	Observations
1. Techniques for graphical representation of the electromagnetic field	Systematic exposition - Guided practical activity	2 Hours
2. Calculation of energy density, momentum, angular momentum of the electromagnetic field, application for some particular cases	Systematic exposition - Guided practical activity	2 Hours
3. Numerical solution of the classical equation of motion for charged particles in electromagnetic field in the relativistic case, study of the effects of the radiation reaction.	Systematic exposition - Guided practical activity	4 Hours
4. Numerical calculation of the observables of the field emitted in the non-linear Thomson scattering of radiation on electrons.	Systematic exposition - Guided practical activity	4 Hours
5. Radiation reaction effects in non-linear Thomson scattering	Systematic exposition - Guided practical activity	2 Hours

References:

J. D. Jackson, Classical electrodynamics, John Wiley and Sons, 1999
C. Joachain, A. Kylstra, R. M. Potvliege, Atoms in intense laser fields, Cambridge University Press, 2012
A. Di Piazza, C. Muller, K. Z. Hatsagortsyan, and C. H. Keitel, Extremely high-intensity laser interactions with fundamental quantum systems, Rev. Mod. Phys. 84, 1177 (2012)
A. Gonoskov et al, Charged particle motion and radiation in strong electromagnetic fields, REv. Mod. Phys. 94, 045001, 2022
D. Suter, The Physics of Laser-Atom Interactions (Cambridge Studies in Modern Optics), 1997
F. V. Hartemann, High-field electrodynamics, CRC press, 2002
J. P. Torres (ed), Twisted photons: applications of light with orbital angular momentum, Wiley-VCH (2011)
J. J. Sakurai, Advanced quantum mechanics, Addison-Wesley, 1967
R. H. Landau, M. J. Paez, and C. C. Bordeianu, Computational Physics: Problem Solving with Python, Wiley, 2024
A. Gezerlis, Numerical Methods in Physics with Python, Cambridge University Press, 2023
S. Spicklemire, Visualizing Quantum Mechanics with Python, CRC Press 2024

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of the methods/physical models - The ability to give specific examples	Written test + oral examination	70%
Practical	Ability to use specific numerical methods for problem solving	Continuous evaluation, Homeworks	30%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale): - At least 50% of exam score and of homework. Requirements for mark 10 (10 points scale): - At least 95% of exam score and of homework.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. Madalina Boca	Conf. Madalina Boca

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.109.2 Quantum Optics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Quantum Optics						
2.2. Teacher	Prof. dr. Iulia Ghiu						
2.3. Tutorials/Practicals instructor(s)	Lect. dr. Andreea Croitoru						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	2	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	28	3.5. Lectures	14	3.6. Tutorials/Practicals/Projects	0/14/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					61
Research in library, study of electronic resources, field research					31
Preparation for practicals/tutorials/projects/reports/homework					30
Tutorat					0
Other activities					0
3.7. Total hours of individual study					122
3.8. Total hours per semester					150
3.9. ECTS					6

4. Prerequisites (if necessary)

4.1. curriculum	Optics, Algebra, Quantum mechanics
4.2. competences	Equations of Mathematical Physics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Video projector
5.2. for tutorials/practicals	Devices in the lab

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Quantization of the electromagnetic field. Entanglement	Systematic exposition.	2 Hours
Bell's inequalities	Systematic exposition.	2 Hours
Quantum random number generator	Systematic exposition.	2 Hours
Quantum key distribution	Systematic exposition.	2 Hours
Michelson interferometer	Systematic exposition.	2 Hours
Interference phenomena with single and double photodetection. The experiment of Hong, Ou, Mandel.	Systematic exposition.	2 Hours
The proposal of Hanbury Brown-Twiss experiment	Systematic exposition.	2 Hours

References:

1. C. Gerry, P. Knight, Introductory Quantum Optics, Cambridge University Press, 2005.
2. M. O. Scully, M. S. Zubairy, Quantum Optics, Cambridge University Press, 2002.
3. Cohen-Tannoudji, Dupont-Roc, and Grynberg, Atom-Photon Interactions, Wiley, 1998.
4. D. F. Walls, G. J. Milburn, Quantum Optics, Springer Verlag, 1994.
5. C. W. Gardiner, Quantum Noise, Springer Verlag, 1991.
6. M. D. Al-Amri, M. M. El-Gomati, M. S. Zubairy (Editors), Optics in Our Time, Springer Open, 2016.
7. quED - Entanglement Demonstrator - A Science Kit for Quantum Physics, www.qutools.com, 2025

7.3 Practicals	Teaching techniques	Observations
Generation of entanglement. Entanglement visibility	Guided practical activity	2 Hours
The experimental proof of CHSH Bell inequality	Guided practical activity	2 Hours
Quantum Random Number Generator	Guided practical activity	2 Hours
Quantum key distribution based on the BB 84 protocol	Guided practical activity	2 Hours
Michelson interferometer	Guided practical activity	2 Hours
Hong-Ou-Mandel interferometer	Guided practical activity	2 Hours
Hanbury Brown-Twiss experiment	Guided practical activity	2 Hours

References:

1. C. Gerry, P. Knight, Introductory Quantum Optics, Cambridge University Press, 2005.
2. M. O. Scully, M. S. Zubairy, Quantum Optics, Cambridge University Press, 2002.
3. D. F. Walls, G. J. Milburn, Quantum Optics, Springer Verlag, 1994.
4. quED - Entanglement Demonstrator - A Science Kit for Quantum Physics, www.qutools.com, 2025.

8. 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 and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Europe (Oxford University, Royal Institute of Technology - Stockholm). The contents is in line with the requirement of the main employers of research institutes and universities.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Lecture	- Clarity and coherence of exposition - Correct use of equations/mathematical methods/physical models and theories - The ability to give specific examples	Written examination	80%
Practical	- Ability to give the interpretation for the experimental results	Evaluation through practical activity	20%
Minimal requirements for passing the exam	Attending minimum 50 % of the lectures and 100% for the lab activities. Mark 5 Minimum 50 % of the requirements for the final mark.		

Date,
13.07.2025

Teacher's
name and signature,
Prof. dr. Iulia Ghiu

Practicals/Tutorials/Project instructor(s),
name and signature
Lect. dr. Andreea Croitoru

Date of approval
15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.110.1 Introduction to quantum theory of identical particles

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Introduction to quantum theory of identical particles
2.2. Teacher	Prof. Dr. Virgil Baran
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Virgil V. Baran

2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	20
Research in library, study of electronic resources, field research	20
Preparation for practicals/tutorials/projects/reports/homework	25
Tutorat	0
Other activities	29
3.7. Total hours of individual study	94
3.8. Total hours per semester	150
3.9. 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 tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
The indistinguishability of quantum particles. Permutation operators. Particle exchange symmetry. Symmetrization postulate for identical quantum particles. Completely symmetric and antisymmetric quantum states.	Systematic exposition - lecture. Examples	2 Hours
Occupation-number representation of quantum mechanics. Fock space.	Systematic exposition - lecture. Examples	2 Hours
Creation and annihilation operators. Vacuum state. Fundamental algebraic relations for fermions and bosons creation/annihilation operators. Field operators. Definition and properties.	Systematic exposition - lecture. Examples	4 Hours
One-body and two-body observables in many-body systems.	Systematic exposition - lecture. Examples	4 Hours
Hartree-Fock approximation. Hartree-Fock method in occupation-number formalism. Density functional theory. Applications	Systematic exposition - lecture. Examples	6 Hours
Coulomb interactions in many electron systems. Jellium model. Basic assumptions and Hamiltonian of the model. Ground state energy in the Hartree-Fock approximation. Hubbard's model in occupation-number formalism. Physical properties.	Systematic exposition - lecture. Examples	4 Hours
Pairing interaction and superconductivity. Experimental observations and phenomenology of superconductivity. London's equations. Effective interaction between electrons and pairing Hamiltonian. Barden-Cooper-Schriffer (BCS) model. Properties. Bogoliubov-Valatin transformation. Quasiparticles. Pairing equations. Properties of superconductors.	Systematic exposition - lecture. Examples	6 Hours

References:

1. J.W. Negele, H. Orland, Quantum Many Particle Systems (Advanced Book Program)
2. P. Nozieres, Theory of Interacting Fermi systems (Advanced Book Program)
3. J.F. Annett, Superconductivity, Superfluidity and Condensates (Oxford University Press)
4. Fetter A.L. , J.D. Walecka Quantum theory of Many Particle systems (McGraw Hill, New-York)
5. P.W. Anderson, Concepts in Solids, World Scientific, 1997
6.W. Nolting, Fundamentals of many-body physics, Springer 2009.

7.2 Tutorials	Teaching techniques	Observations
Fermi gas in ground state: Fermi's sea, relationship between density and momentum. Applications.	Problem solving	2 Hours
One-particle density matrix for fermion systems. Pair correlation function for fermions and bosons. Definition, properties, physical consequences.	Problem solving	4 Hours
Observables of interest in terms on creation and annihilation operators: densities, currents.	Problem solving	4 Hours

Hartree-Fock approximation: examples. Koopmans' theorem. Density functional theory. Hubbard model	Problem solving	8 Hours
Bogoliubov Theory of the Weakly Interacting Bose Gas	Problem solving	4 Hours
Cooper pair problem. Phonon-electron interaction. Superconductivity: constant coupling function. Ground state energy. Derivation of gap equation. Physical interpretation.	Problem solving	6 Hours

References:

1. P.W. Anderson, Concepts in Solids, World Scientific, 1997
2.W. Nolting, Fundamentals of many-body physics, Springer 2009.
3. P.A. Martin, F. Rothen, Many-body problems and quantum field theory, Springer, 2002

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. Dr. Virgil Baran	Lect. Dr. Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026

DO.110.2 Theory of critical phenomena

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Theory of critical phenomena
2.2. Teacher	Prof. Dr. Virgil Baran
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Virgil V. Baran

2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	20
Research in library, study of electronic resources, field research	20
Preparation for practicals/tutorials/projects/reports/homework	25
Tutorat	0
Other activities	29
3.7. Total hours of individual study	94
3.8. Total hours per semester	150
3.9. 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 tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Continuous phase transitions and critical points Critical phenomena in nature: liquid-gas phase transition, binary fluid, the ferromagnetic-paramagnetic transition, the transition to superconductivity, the He I-He II transition. Fundamental concepts: order parameter, critical exponents, correlation functions, scale invariance, classes of universality.	Systematic exposition - lecture. Examples	6 Hours
Models for description of phase transitions Ising models in one, two and three dimensions. Networks models, XY model, Heisenberg model, Potts model, percolation model	Systematic exposition - lecture. Examples	8 Hours
Mean-field theory for critical behaviour Theoretical framework. Landau theory. Critical exponents in Landau theory	Systematic exposition - lecture. Examples	6 Hours
Renormalization group method The basic principles of the method. Renormalization group transformations and recurrence relations.	Systematic exposition - lecture. Examples	8 Hours

References:

1. J.J. Binney, N.J. Dowrick, A.J. Fisher, M.E.J. Newman, The Theory of Critical Phenomena. An introduction to the renormalization Group, (Oxford UP 1995)
2. Leo P. Kadanoff, Statistical Physics. Statics, Dynamics and Renormalization. (World Scientific, 2001)
3. C. Domb, The Critical Point, (Taylor and Franciscs, 1996)

7.2 Tutorials	Teaching techniques	Observations
The Van der Waals model for the liquid-gas phase transition: critical exponents in the mean-field approximation.	Problem solving	4 Hours
The transfer matrix. The Duality transformation. Onsager solution for Ising model in two dimensions.	Problem solving	4 Hours
The renormalization group method for Ising model in two dimensions. The Monte-Carlo method for Ising model in three dimensions	Problem solving	5 Hours
The Momentum-Shell Renormalization Group	Problem solving	5 Hours
Percolation	Problem solving	4 Hours
Fixed points of the renormalization group transformations: the physical meaning and properties. Linearized transformations around the fixed point. The origin of the scale behaviour. Renormalization group in differential form.	Problem solving	6 Hours

References:

1. N. Goldenfeld, Lectures on phase transitions and the renormalization group (Adison-Wesley PC, 1992)
2. Franz Schwabl, Statistical mechanics, Springer-Verlag Berlin Heidelberg 2006

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. Dr. Virgil Baran	Lect. Dr. Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.111.1 Quantum information and communication

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Quantum information and communication
2.2. Teacher	Prof. dr. Iulia Ghiu
2.3. Tutorials/Practicals instructor(s)	Lect. dr. Andreea Croitoru

2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	1/1/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	14/14/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	47
Research in library, study of electronic resources, field research	24
Preparation for practicals/tutorials/projects/reports/homework	23
Tutorat	0
Other activities	0
3.7. Total hours of individual study	94
3.8. Total hours per semester	150
3.9. ECTS	6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, Optics, Equations of Mathematical Physics
4.2. competences	Knowledge about: Algebra, solving differential equations

5. Conditions/Infrastructure (if necessary)

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

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Definition of the qubit. Two-qubit systems. Entangled states. Einstein-Podolsky-Rosen paradox. Bell's inequalities	Systematic exposition. Examples	4 Hours
The density operator for a spin-1/2 particle. The Bloch vector. The reduced density operator. Schmidt decomposition. Purifications	Systematic exposition. Examples	2 Hours
Quantum teleportation. Many-to-many teleportation	Systematic exposition. Examples	2 Hours
No-cloning theorem. Superdense coding. Shannon entropy and von Neumann entropy.	Systematic exposition. Examples	2 Hours
Trace distance. Polar decomposition. Definition of the fidelity. Uhlmann's theorem. Properties of the fidelity. Approximate cloning machine	Systematic exposition. Examples	4 Hours
Quantum cryptography	Systematic exposition. Examples	2 Hours
Quantum gates. Deutsch's algorithm. Deutsch-Jozsa algorithm	Systematic exposition. Examples	2 Hours
Bernstein-Vazirani algorithm. Simon algorithm	Systematic exposition. Examples	2 Hours
Grover's quantum search algorithm. Shor's factoring algorithm	Systematic exposition. Examples	4 Hours
Quantum channels	Systematic exposition. Examples	2 Hours
Description of the IBM-Q quantum computer in the cloud and its application for the implementation of quantum algorithms	Systematic exposition. Examples	2 Hours

References:

1. M. A. Nielsen and I. L. Chuang, Quantum computation and quantum information, Cambridge University Press, Cambridge, 2000.
2. Asher Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers, 1993.
3. D. Bouwmeester, A. Ekert, and A. Zeilinger, The Physics of Quantum Information, Springer Verlag, 2000.
4. S. M. Barnett, Quantum Information, Oxford Master series in physics, Oxford University Press, 2009.
5. Iulia Ghiu, Quantum Information, Lecture notes (2025)

7.2 Tutorials	Teaching techniques	Observations
Applications of the CHSH-Bell inequality. The analysis of the density operator for a qubit.	Problem solving	2 Hours
Operator functions. The reduced density operators. Finding the Schmidt decomposition of a bipartite state. The analysis of the density operator of two spin-1/2 particles. The purity of a mixed state.	Problem solving	4 Hours
Computing the trace distance and the fidelity for some particular mixed states	Problem solving	4 Hours
The generalized quantum teleportation and the evaluation of the average fidelity. The quantum circuit for the gates: SWAP, Toffoli, Fredkin	Problem solving	4 Hours

References:
1. M. A. Nielsen and I. L. Chuang, Quantum computation and quantum information, Cambridge University Press, Cambridge, 2000. 2. D. Bouwmeester, A. Ekert, and A. Zeilinger, The Physics of Quantum Information, Springer Verlag, 2000. 3. S. M. Barnett, Quantum Information, Oxford Master series in physics, Oxford University Press, 2009. 4. M. M. Wilde, Quantum Information Theory, Cambridge University Press, 2017. 5. W. H. Steeb, Y. Hardy, Problems and solutions in quantum computing and quantum information, World Scientific, 2004.

7.3 Practicals	**Teaching techniques**	**Observations**
Symbolic evaluation of the proposed problems	Guided practical activity	6 Hours
Applications using the IBM-Q quantum computer in the cloud	Guided practical activity	8 Hours

References:
1. M. A. Nielsen and I. L. Chuang, Quantum computation and quantum information, Cambridge University Press, Cambridge, 2000. 2. D. Bouwmeester, A. Ekert, and A. Zeilinger, The Physics of Quantum Information, Springer Verlag, 2000. 3. S. M. Barnett, Quantum Information, Oxford Master series in physics, Oxford University Press, 2009. 4. M. M. Wilde, Quantum Information Theory, Cambridge University Press, 2017.

8. 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 and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Europe (Oxford University, Royal Institute of Technology - Stockholm). The contents is in line with the requirement of the main employers of research institutes and universities.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of equations/mathematical methods/physical models and theories - The ability to give specific examples	Written examination	100%
Minimal requirements for passing the exam	Attending minimum 50 % of the lectures, 50 % of the tutorials and 100% for the lab activities. Mark 5 Minimum 50 % of the requirements for the final mark.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. dr. Iulia Ghiu	Lect. dr. Andreea Croitoru

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.111.2 Collision theory

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Collision theory						
2.2. Teacher	Conf. Madalina Boca						
2.3. Tutorials/Practicals instructor(s)	Conf. Madalina Boca						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	1/1/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	14/14/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					40
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					24
Tutorat					0
Other activities					0
3.7. Total hours of individual study					94
3.8. Total hours per semester					150
3.9. ECTS					6

4. Prerequisites (if necessary)

4.1. curriculum	Quantum Mechanics, Classical Electrodynamics, Equations of Mathematical Physics
4.2. competences	Good understanding of principles of quantum mechanics, Classical electrodynamics, Basic elements of Computational Physics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Room with video projector, internet connection
5.2. for tutorials/practicals	Room with video projector, internet connection

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
1. Classification of collisions. Cross sections. Potential scattering, The scattering solution and the scattering amplitude.	Systematic exposition - lecture. Examples	2 Hours
2. Scattering on central potentials, partial waves, phase shifts, phase shifts method. Resonances, Breit-Wigner formula, Scattering on Coulomb potential and potentials with Coulomb tail.	Systematic exposition - lecture. Examples	2 Hours
3. The Lippmann-Schwinger equation. Green functions and operators. Born series method.	Systematic exposition - lecture. Examples	4 Hours
4. Scattering on non-central potential	Systematic exposition - lecture. Examples	4 Hours
5. Scattering of particles with spin. Scattering of identical particles	Systematic exposition - lecture. Examples	6 Hours
6. The time dependent integral equation of potential scattering. Propagators.	Systematic exposition - lecture. Examples	4 Hours
7. Laser assisted collisions, general formalism. R-matrix Floquet theory	Systematic exposition - lecture. Examples	6 Hours

References:

1. R. M. Dreizler, T. Kirchner, and Cora S. Ludde, Quantum Collision Theory of Nonrelativistic Particles: An Introduction, Springer, 2022
2. M. L. Goldberger, K. M. Watson, Collision Theory, Dover Publications, Incorporated, 2014
3. C.J. Joachain, Quantum collision theory, North-Holland, 1975
4. P. Roman, Advanced quantum theory, Addison-Wesley Pub. Co., 1965
5. M. Dondera, V. Florescu, Fizica atomica teoretica, Ed. UB, 2005
6. J. Taylor, Scattering theory: the quantum theory of non-relativistic collisions, John Willey and Sons, 1972

7.2 Tutorials	**Teaching techniques**	**Observations**
The optical theorem. The Wronskian theorem and applications.	Problem solving	2 Hours
Finite range potentials. The effective range formalism	Problem solving	2 Hours
Analytical properties of the scattering amplitude.	Problem solving	4 Hours
Applications of the time dependent perturbation theory in the scattering theory	Problem solving	4 Hours
The Born approximation; examples	Problem solving	2 Hours

References:

1. R. M. Dreizler, T. Kirchner, and Cora S. Ludde, Quantum Collision Theory of Nonrelativistic Particles: An Introduction, Springer, 2022
2. M. L. Goldberger, K. M. Watson, Collision Theory, Dover Publications, Incorporated, 2014
3. C.J. Joachain, Quantum collision theory, North-Holland, 1975
4. P. Roman, Advanced quantum theory, Addison-Wesley Pub. Co., 1965
5. M. Dondera, V. Florescu, Fizica atomica teoretica, Ed. UB, 2005
6. J. Taylor, Scattering theory: the quantum theory of non-relativistic collisions, John Willey and Sons, 1972

7.3 Practicals	**Teaching techniques**	**Observations**

1. Numerical solution of the time-dependent Schrodinger equation, numerical modelling of quantum potential scattering	Guided practical activity	4 Hours
2. Numerical solution of the time independent Schrodinger equation for central potentials, calculation of phase shifts	Guided practical activity	4 Hours
3. Numerical study of the Coulomb effects in potential scattering	Guided practical activity	2 Hours
4. Numerical study of the time evolution of quantum systems in external fields	Guided practical activity	4 Hours

References:

1. J. M. Kinder and P. Nelson, A Student's Guide to Python for Physical Modeling, Princeton University Press, 2021
2. M. Bestehorn, Computational Physics, De Gruyter 2023

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	Clarity and coherence of exposition Correct use of the methods/ physical models The ability to give specific examples	Written test and oral examination	70%
Tutorial	Ability to use specific problem solving methods	Homeworks	15%
Practical	Ability to use numerical methods to solve specific problems	Homeworks	15%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale): - At least 50% of exam score and of homework. Requirements for mark 10 (10 points scale): - At least 95% of exam score and of homework.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. Madalina Boca	Conf. Madalina Boca

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026

DO.202.1 Advanced methods in statistical physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Advanced methods in statistical physics
2.2. Teacher	Lect. Dr. Dragoş Iustin PALADE
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Dragoş Iustin PALADE

2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/14/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	67
Research in library, study of electronic resources, field research	33
Preparation for practicals/tutorials/projects/reports/homework	33
Tutorat	0
Other activities	0
3.7. Total hours of individual study	133
3.8. Total hours per semester	175
3.9. ECTS	7

4. Prerequisites (if necessary)

4.1. curriculum	Quantum mechanics, 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 tutorials/practicals	Video projector

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Revision of elements of statistical and quantum mechanics.	Systematic exposition - lecture. Examples	2 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
Quantum hydrodynamic models. Electrostatic waves.	Systematic exposition - lecture. Examples	2 Hours
Ginzburg–Landau theory of superconductivity. Basic equations. From type-I superconductor to type-II superconductors.	Systematic exposition - lecture. Examples	4 Hours

References:

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

7.3 Practicals	Teaching techniques	Observations
Galitskii-Migdal theorems. The relation with the observables. Differential equations. Correlation functions:definition, general properties, the similarity with the Green functions.	Problem solving	2 Hours
Applications of the Green formalism for various systems. The Thomas-Fermi approximation and its extensions.	Problem solving	2 Hours
Applications of Density Functional Theory	Problem solving	2 Hours
Collective dynamics of Bose-Einstein condensates	Problem solving	2 Hours
The theory of compound fermions	Problem solving	2 Hours
Superconductivity: surface energy and thermodynamic critical field in Ghinzburg-Landau theory. Vortex lattice. Josephson tunnelling.	Problem solving	2 Hours
		2 Hours

References:

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

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Practical	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks. At least 90% of laboratory attendance. At least 50% of lecture attendance.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Dragoş Iustin PALADE	Lect. Dr. Dragoş Iustin PALADE

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026

DO.202.2 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	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Computational methods for electronic structures of condensed systems						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	examen	2.7.Classification	DA

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/14/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					67
Research in library, study of electronic resources, field research					33
Preparation for practicals/tutorials/projects/reports/homework					33
Tutorat					0
Other activities					0
3.7. Total hours of individual study					133
3.8. Total hours per semester					175
3.9. ECTS					7

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R3. Employs computational and numerical techniques for analysis and simulation. R5. Evaluates scientific literature and data with critical judgment.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R3. Takes responsibility for applying suitable research methods. R5. Performs independent investigations with critical awareness.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam			

Date, 13.07.2025

Teacher's name and signature,

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

Date of approval 15.07.2025

Head of department name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.203.1 Computational methods in modern physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Computational methods in modern physics						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/14/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					30
Research in library, study of electronic resources, field research					30
Preparation for practicals/tutorials/projects/reports/homework					30
Tutorat					0
Other activities					43
3.7. Total hours of individual study					133
3.8. Total hours per semester					175
3.9. ECTS					7

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 tutorials/practicals	Scientific computing laboratory

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
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 describing particle dynamics. Boris algorithm for particle propagation over time. Courant stability condition.	Systematic exposition - lecture. Examples	4 Hours
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

References:

1. B. Leimkuhler şi S. Reich, Simulating Hamiltonian dynamics, Cambridge University Press, 2004.
2. D.F. Griffiths, J.W. Dold şi D.J. Silvester, Essential partial differential equations. Analytical and computational aspects, Springer, 2015.
3. S. Mazumder, Numerical methods for partial differential equations. Finite difference and finite volume methods, Academic Press, 2016.
4. S.E. Koonin şi D.C. Meredith, Computational physics. Fortran versions, Perseus Books, 1998.
5. P. Mulser şi D. Bauer, High power laser-matter interaction, Springer, 2010.
6. P.G. Reinhard şi E. Suraud, Introduction to cluster dynamics, Wiley-VCH, 2004.
7. K. Langanke, J.A. Maruhn şi S.E. Koonin, Eds., Computational Nuclear Physics 2. Nuclear Reactions, Springer, 1993.
8. T.D. Arber et al., Contemporary particle-in-cell approach to laser-plasma modelling, Plasma Phys. Control. Fusion 57, 113001 (2015)

7.3 Practicals	**Teaching 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	2 Hours
The numerical solution of the Schrödinger equation. Code in Octave/python/C/C ++	Supervised practical activity	3 Hours
Numerical solution of Maxwell equations. Code in Octave/python/C/C++	Supervised practical activity	3 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	3 Hours
Numerical solution of the Vlasov equation. Use of existing FORTRAN programs	Supervised practical activity	3 Hours

References:

1. B. Leimkuhler şi S. Reich, Simulating Hamiltonian dynamics, Cambridge University Press, 2004.
2. K.W. Morton şi D.F. Mayers, Numerical solution of partial differential equations, Cambridge University Press, 2005.
3. Yu.N. Grigoryev et al., Numerical particle-in-cell methods: Theory and applications, de Gruyter, 2002.

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples		60%
Minimal requirements for passing the exam			

Date,

13.07.2025

Teacher's
name and signature,

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

Date of approval

15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.203.2 Theory of intense laser radiation interaction with atomic and nuclear systems

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Theory of intense laser radiation interaction with atomic and nuclear systems
2.2. Teacher	Conf. M. Boca
2.3. Tutorials/Practicals instructor(s)	Conf. M. Boca

2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	42	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/14/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	67
Research in library, study of electronic resources, field research	33
Preparation for practicals/tutorials/projects/reports/homework	33
Tutorat	0
Other activities	0
3.7. Total hours of individual study	133
3.8. Total hours per semester	175
3.9. ECTS	7

4. Prerequisites (if necessary)

4.1. curriculum	Programing languages, Quantum mechanics, Nuclear physics, Classical electrodynamics
4.2. competences	Understanding of some techniques in numerical methods in physics,

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Room with videoprojector, internet access
5.2. for tutorials/practicals	Computer Room with videoprojector, internet access

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.

Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
1. Fundamentals of atomic and nuclear systems	Systematic exposition - lecture. Examples	2 Hours
2. The time evolution of atomic systems in interaction with intense radiation fields. Perturbative vs non perturbative regime.	Systematic exposition - lecture. Examples	4 Hours
3. Relativistic effects in the interaction of atomic systems with intense electromagnetic fields; applications for ionization and high harmonic generation	Systematic exposition - lecture. Examples	4 Hours
4. Boltzmann-Vlasov and Boltzmann-Maxwell transport equations	Systematic exposition - lecture. Examples	4 Hours
5. Test particle method for the numerical treatment of Vlasov-type equations. Derivation of particle-in-cell equations	Systematic exposition - lecture. Examples	4 Hours
6. The interaction of intense laser radiation with atomic nuclei and metal clusters. Experimental and theoretical results.	Systematic exposition - lecture. Examples	6 Hours
7. Presentation of future experiments at the European research infrastructure Extreme Light Infrastructure	Systematic exposition - lecture. Examples	4 Hours

References:

P.M. Bellan, Fundamentals of plasma physics, Cambridge University Press, 2008
P. Mulser şi D. Bauer, High power laser-matter interaction, Springer, 2010
K. Langanke, J.A. Maruhn şi S.E. Koonin, Eds., Computational Nuclear Physics 2. Nuclear reactions, Springer, 1993
P.G. Reinhard şi E. Suraud, Introduction to cluster dynamics, Wiley-VCH, 2004
C. Joachain, A. Kylstra, R. M. Potvliege, Atoms in intense laser fields, Cambridge University Press, 2012
D. Suter, The Physics of Laser-Atom Interactions (Cambridge Studies in Modern Optics), 1997
F. V. Hartemann, High-field electrodynamics, CRC press, 2002
P. Michel, Introduction to Laser-Plasma Interactions, Springer International Publishing, 2023

7.3 Practicals	**Teaching techniques**	**Observations**
1. Numerical methods for solving the time-dependent Schrodinger equation for atomic systems in interaction with electromagentic fields. Comparisson with known analytical results	Guided practical activity; problem solving	6 Hours
2. Numerical solution of Vlasov-type equations. Numerical determination of collective modes (especially pygmy dipole resonance and giant dipole resonance) in different atomic species	Guided practical activity; problem solving	6 Hours
3. Numerical study of the interaction of laser pulses with metallic clusters	Guided practical activity; problem solving	2 Hours

References:
P.M. Bellan, Fundamentals of plasma physics, Cambridge University Press, 2008 P. Mulser şi D. Bauer, High power laser-matter interaction, Springer, 2010 K. Langanke, J.A. Maruhn şi S.E. Koonin, Eds., Computational Nuclear Physics 2. Nuclear reactions, Springer, 1993 P.G. Reinhard şi E. Suraud, Introduction to cluster dynamics, Wiley-VCH, 2004 C. Joachain, A. Kylstra, R. M. Potvliege, Atoms in intense laser fields, Cambridge University Press, 2012 D. Suter, The Physics of Laser-Atom Interactions (Cambridge Studies in Modern Optics), 1997 F. V. Hartemann, High-field electrodynamics, CRC press, 2002 P. Michel, Introduction to Laser-Plasma Interactions, Springer International Publishing, 2023

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	Clarity and coherence of exposition Correct use of the methods/ physical models The ability to give specific examples	Written test and oral examination	70%
Practical	Ability to use numerical methods to solve specific problems	Homeworks	30%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale): - At least 50% of exam score and of homework. Requirements for mark 10 (10 points scale): - At least 95% of exam score and of homework.		

Date,
13.07.2025

Teacher's
name and signature,
Conf. M. Boca

Practicals/Tutorials/Project instructor(s),
name and signature
Conf. M. Boca

Date of approval
15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026

DO.204.1 Non-abelian gauge theories and standard model of elementary particles

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Non-abelian gauge theories and standard model of elementary particles						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	40	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	20/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					80
Research in library, study of electronic resources, field research					40
Preparation for practicals/tutorials/projects/reports/homework					40
Tutorat					0
Other activities					0
3.7. Total hours of individual study					160
3.8. Total hours per semester					200
3.9. ECTS					8

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam			

Date,

13.07.2025

Teacher's name and signature,

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

Date of approval

15.07.2025

Head of department name and signature

Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DO.204.2 Theory of hadronic matter in extreme conditions and quark-gluon plasma

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Theory of hadronic matter in extreme conditions and quark-gluon plasma
2.2. Teacher	Prof. Dr. Virgil Baran
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Virgil V. Baran

2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	40	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	20/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	30
Research in library, study of electronic resources, field research	15
Preparation for practicals/tutorials/projects/reports/homework	20
Tutorat	0
Other activities	95
3.7. Total hours of individual study	160
3.8. Total hours per semester	200
3.9. ECTS	8

4. Prerequisites (if necessary)

4.1. curriculum	Advanced quantum mechanics, statistical quantum physics, introduction to quantum field theory and elementary particles, Theory of nuclear systems and photonuclear reactions
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	PCs with intranet connection to the local computing cluster

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Properties of nuclear matter at finite temperature. Nuclear multifragmentation and liquid-gas phase transition in binary systems. Reaction mechanisms' evolution with the energy and impact parameter in heavy ion collisions.	Systematic exposition - lecture. Examples	5 Hours
Quarks and irreducible representations of the SU(3) group. Classification of strongly interacting elementary particles. Fundamentals of Quantum Chromodynamics.	Systematic exposition - lecture. Examples	5 Hours
Nonperturbative properties of strongly interacting matter: deconfinement and spontaneous breaking of the chiral symmetry. Order parameters for the chiral phase transition and for the confinement-deconfinement phase transition. Structure of the QCD vacuum.	Systematic exposition - lecture. Examples	5 Hours
Phenomelogical models of the nucleon. The Nambu-Jona-Lasinio model. Analogies and differences between the electromagnetic and quark-gluon plasmas. Experimental evidence of quark-gluon plasma formation in the RHIC and LHC experiments. Description of the quark-gluon plasma dynamics within transport models.	Systematic exposition - lecture. Examples	5 Hours

References:

D. Durand, E. Suraud, B. Tamain, Nuclear dynamics in nucleonic regime, IOP 2001

K.Yagi, T. Hatsuda, Y. Miake, Quark gluon plasma. From Big Bang to Little Bang, Cambridge UP, 2005

W. Greiner, S. Schramm, E. Stein, Quantum Chromodynamics, Springer 2007

J. Letessier,J. Rafelski, Hadrons and quark-gluon plasma, Cambridge UP 2004

R. Balian, From Microphysics to Macrophysics Vol. 1, 2, Springer 2006

7.2 Tutorials	Teaching techniques	Observations
Study of instabilities in asymmetric nuclear matter. The relativistic sigma-omega model of nuclear matter.	Problem solving	7 Hours
Quark energies and wavefunctions, gluon corrections, charge distribution, magnetic moment of the proton within the MIT bag model of the nucleon.	Problem solving	7 Hours
Equation of state for quark and gluon systems at finite density and temperature.	Problem solving	6 Hours

References:
Durand, E. Suraud, B. Tamain, Nuclear dynamics in nucleonic regime, IOP 2001 K.Yagi, T. Hatsuda, Y. Miake, Quark gluon plasma. From Big Bang to Little Bang, Cambridge UP, 2005 W. Greiner, S. Schramm, E. Stein, Quantum Chromodynamics, Springer 2007 J. Letessier,J. Rafelski, Hadrons and quark-gluon plasma, Cambridge UP 2004 R. Balian, From Microphysics to Macrophysics Vol. 1, 2, Springer 2006

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	-Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. Dr. Virgil Baran	Lect. Dr. Virgil V. Baran

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.106 Volunteering

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	0	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/0/0
3.4. Total hours per semester	0	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	13
Research in library, study of electronic resources, field research	6
Preparation for practicals/tutorials/projects/reports/homework	6
Tutorat	0
Other activities	0
3.7. Total hours of individual study	25
3.8. Total hours per semester	25
3.9. ECTS	1

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R10. The student/graduate acquires civic competences.
Skills	R10. The student/graduate improves communication skills.
Responsibility and autonomy	R10. Shows spirit of initiative and entrepreneurship.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Minimal requirements for passing the exam	

Date, 13.07.2025

Teacher's name and signature,

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

Date of approval 15.07.2025

Head of department name and signature

Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.112 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 and Biophysics
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Physics of mesoscopic systems						
2.2. Teacher	Prof. dr. Lucian Ion						
2.3. Tutorials/Practicals instructor(s)	drd. Amanda Preda						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	examen	2.7.Classification	DS

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	28/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					22
Research in library, study of electronic resources, field research					11
Preparation for practicals/tutorials/projects/reports/homework					11
Tutorat					0
Other activities					0
3.7. Total hours of individual study					44
3.8. Total hours per semester					100
3.9. ECTS					4

4. Prerequisites (if necessary)

4.1. curriculum	Electrodynamics, Solid state physics
4.2. competences	knowledge of electronic and optical properties of solids

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	room with multimedia infrastructure
5.2. for tutorials/practicals	computer room

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R5. Evaluates scientific literature and data with critical judgment.
Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R5. Performs independent investigations with critical awareness.

7. Contents

7.1 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¡=2. Case d¿2. Metal-insulator transition	Systematic exposition - lecture. Examples.	6 Hours
Quantum interference effects in charge transport. Landauer-Buttiker formalism. Applications.	Systematic exposition - lecture. Examples.	4 Hours
Charge 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:

1. D.K. Ferry, S.M. Goodnick, Transport in nanostructures (Cambridge University Press, Cambridge, UK, 1997).
2. P.A. Lee, T.V. Ramakrishnan, Rev. Mod. Phys. 57, 287 (1985).
3. H. Bouchiat, Y. Gefen, S. Gueron, G. Montambaux, J. Dalibard (Eds.), Nanophysics: Coherence and Transport (Elsevier, Amsterdam, Netherland, 2005).
4. V.F. Gantmakher, Electrons and disorder în solids (Clarendon Press, Oxford, UK, 2005)
5. L. Ion, Course notes

7.2 Tutorials	**Teaching techniques**	**Observations**
Electronic states în mesoscopic systems. Envelope wavefunction method. Aplications.	Exposition. Guided work	4 Hours
Effect of disorder in 1D and 2D electronic systems.	Exposition. Guided work	4 Hours
Electronic states in 2D electron systems in magnetic fields. Disorder effects.	Exposition. Guided work	6 Hours
Charge transport in mesoscopic structures. Landauer-Buttiker formalism.	Exposition. Guided work	6 Hours
Weak localization regime.	Exposition. Guided work	4 Hours
Electron-phonon interaction în low-dimensional systems. Peierls transition.	Exposition. Guided work	4 Hours

References:

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

8. 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-Saclay, 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).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	- Use of specific physical and mathematical methods and techniques;	Homework, research projects	50%

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

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. dr. Lucian Ion	drd. Amanda Preda

Date of approval	Head of department name and signature
15.07.2025	Assoc. prof. Adrian RADU

Syllabus

Academic year 2025/2026
DFC.113 Advanced methods for parallel computing

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Electricity, Solid State and Biophysics
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Advanced methods for parallel computing						
2.2. Teacher	Prof. dr. Lucian Ion						
2.3. Tutorials/Practicals instructor(s)	Lect. dr. Claudiu Locovei						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	colocviu	2.7.Classification	DC

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/28/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					22
Research in library, study of electronic resources, field research					11
Preparation for practicals/tutorials/projects/reports/homework					11
Tutorat					0
Other activities					0
3.7. Total hours of individual study					44
3.8. Total hours per semester					100
3.9. ECTS					4

4. Prerequisites (if necessary)

4.1. curriculum	C/C++ and Python programming
4.2. competences	C/C++ and Python programming techniques

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	room with multimedia infrastructure
5.2. for tutorials/practicals	computer room

6. Learning outcomes

Knowledge	R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions.
Skills	R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment.
Responsibility and autonomy	R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**

Characteristics of parallel computing models. Performance indicators.	Systematic exposition - lecture. Examples.	4 Hours
MPI standard. MPI programming techniques	Systematic exposition - lecture. Examples.	10 Hours
OpenMP programming techniques	Systematic exposition - lecture. Examples.	8 Hours
Algorithms for parallel computing	Systematic exposition - lecture. Examples.	6 Hours

References:

1. Michael J. Quinn, Parallel Programming in C with MPI and OpenMP (McGraw-Hill, New York, USA, 2003).
2. T. Rauber, G. Runger, Parallel Programming for multicore and cluster systems (Springer-Verlag, Berlin, Germany, 2010).
3. W. Gropp, E. Lusk, A. Skjellum, Using MPI: portable parallel programming with the Message-Passing Interface (MIT Press, Cambridge, USA, 2014).
4. L. Ion, Note de curs (pdf)

7.3 Practicals	**Teaching techniques**	**Observations**
Functions/subroutines for MPI environment management. Point-to-point communications	Guided practical work	4 Hours
Groups and communicators in the MPI environment. Virtual topologies.	Guided practical work	4 Hours
Derived data types. One-sided communication operations	Guided practical work	4 Hours
Dynamic process management in MPI. I/O parallel operations.	Guided practical work	4 Hours
OpenMP multithreading	Guided practical work	4 Hours
Applications: transport in mesoscopic systems; electronic structure of materials	Guided practical work	8 Hours

References:

1. G.A. Nemneş, T.L. Mitran, A. Nicolaev, L. Ion, Aplicaţii MPI pentru sisteme de calcul paralel – îndrumător de laborator (Editura Universităţii din Bucureşti, Bucureşti, 2015).
2. Michael J. Quinn, Parallel Programming in C with MPI and OpenMP (McGraw-Hill, New York, USA, 2003).
2. Michael J. Quinn, Parallel Programming in C with MPI and OpenMP (McGraw-Hill, New York, USA, 2003).
3. W. Gropp, E. Lusk, A. Skjellum, Using MPI: portable parallel programming with the Message-Passing Interface (MIT Press, Cambridge, USA, 2014).

8. 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).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Correct use of the studied programming models and techniques; - Ability to solve specific problems.	Exam	60%
Practical	- Knowledge of parallel programming techniques and of the parallel computing infrastructure;	Homeworks	40%

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). Requirements for mark 10 (10 points scale) Correct solving of subjects indicated as required for obtaining mark 10 (final exam and homeworks).(operaţii de comunicare MPI). Obţinerea notei 10: - Abilităţi, cunoştinţe profund argumentate - Capacitate demonstrată de analiză a problemelor, rezolvarea corectă a tuturor subiectelor

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. dr. Lucian Ion	Lect. dr. Claudiu Locovei

Date of approval	Head of department name and signature
15.07.2025	Assoc. prof. Adrian RADU

Syllabus

Academic year 2025/2026
DFC.114 Volunteering

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	0	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/0/0
3.4. Total hours per semester	0	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					13
Research in library, study of electronic resources, field research					6
Preparation for practicals/tutorials/projects/reports/homework					6
Tutorat					0
Other activities					0
3.7. Total hours of individual study					25
3.8. Total hours per semester					25
3.9. ECTS					1

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R10. The student/graduate acquires civic competences.
Skills	R10. The student/graduate improves communication skills.
Responsibility and autonomy	R10. Shows spirit of initiative and entrepreneurship.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Minimal requirements for passing the exam	

Date,

13.07.2025

Teacher's
name and signature,

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

Date of approval

15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.115 Data science and computational electronic structure methods for soft-end bio-matter

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Data science and computational electronic structure methods for soft-end bio-matter						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	examen	2.7.Classification	

3. Total estimated time

3.1. Hours per week	2	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	0/1/0
3.4. Total hours per semester	28	3.5. Lectures	14	3.6. Tutorials/Practicals/Projects	0/14/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					13
Research in library, study of electronic resources, field research					6
Preparation for practicals/tutorials/projects/reports/homework					6
Tutorat					0
Other activities					0
3.7. Total hours of individual study					25
3.8. Total hours per semester					53
3.9. ECTS					3

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems. R9. The student/graduate contributes to teamwork and interdisciplinary projects, managing resources efficiently.
Skills	R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains. R9. Collaborates across disciplines and manages research workflows.

Responsibility and autonomy	R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks. R9. Contributes actively to research teams and professional communities.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Minimal requirements for passing the exam			

Date,

13.07.2025

Teacher's
name and signature,

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

Date of approval

15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.205 Computational approaches in high-energy physics

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Computational approaches in high-energy physics						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	56	3.5. Lectures	28	3.6. Tutorials/Practicals/Projects	0/28/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					7
Research in library, study of electronic resources, field research					6
Preparation for practicals/tutorials/projects/reports/homework					6
Tutorat					0
Other activities					0
3.7. Total hours of individual study					19
3.8. Total hours per semester					75
3.9. ECTS					3

4. Prerequisites (if necessary)

4.1. curriculum	Algebra, Analysis, Quantum mechanics
4.2. competences	Knowledge about: mechanics, solving differential equations

5. Conditions/Infrastructure (if necessary)

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

6. Learning outcomes

Knowledge	R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Computational methods in nuclear structure: algorithms for nuclear models, numerical solutions for the study of nuclear matter properties in Hartree-Fock theory with pairing interaction, numerical approaches in RPA theory for collective nuclear response.	Systematic exposition - lecture. Examples	10 Hours
Computational methods for nuclear reactions description.	Systematic exposition - lecture. Examples	9 Hours
Numerical methods for matter structure investigation. Deep inelastic scattering. Hadron-hadron scattering.	Systematic exposition - lecture. Examples	9 Hours
References: 1. K. Langanke, J.A. Maruhn, S.E. Koonin, Computational Nuclear Physics, vol 1 and 2, Springer-Verlag, 1991 2. R. K. Ellis, W. J. Stirling, and B. R. Webber, QCD and collider physics, Cambridge University Press, 2003		
7.3 Practicals	**Teaching techniques**	**Observations**
Numerical applications to collective geometric model study and to interacting boson approximation study.	Problem solving	7 Hours
Numerical simulations for relativistic kinematics and cross-sections for elementary particles collisions.	Problem solving	7 Hours
Electron-proton collisions associated to HERA-DESY experiments.	Problem solving	7 Hours
Proton-proton collisions associated to LHC-CERN experiments.	Problem solving	7 Hours
References:		

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Practical	- Ability to use specific problem solving methods	Homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date, 13.07.2025	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
Date of approval 15.07.2025		Head of department name and signature Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.206 Volunteering

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Volunteering
2.2. Teacher	
2.3. Tutorials/Practicals instructor(s)	

2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	0	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/0/0
3.4. Total hours per semester	0	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	13
Research in library, study of electronic resources, field research	6
Preparation for practicals/tutorials/projects/reports/homework	6
Tutorat	0
Other activities	0
3.7. Total hours of individual study	25
3.8. Total hours per semester	25
3.9. ECTS	1

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R10. The student/graduate acquires civic competences.
Skills	R10. The student/graduate improves communication skills.
Responsibility and autonomy	R10. Shows spirit of initiative and entrepreneurship.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Minimal requirements for passing the exam	

Date, 13.07.2025

Teacher's name and signature,

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

Date of approval 15.07.2025

Head of department name and signature Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026

DFC.211 Extensions of the standard model of elementary particles

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Extensions of the standard model of elementary particles						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	40	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	20/0/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	11
Research in library, study of electronic resources, field research	10
Preparation for practicals/tutorials/projects/reports/homework	10
Tutorat	0
Other activities	4
3.7. Total hours of individual study	35
3.8. Total hours per semester	75
3.9. ECTS	3

4. Prerequisites (if necessary)

4.1. curriculum	Quantum field theory, Statistical mechanics, Theory of relativity, Nuclear physics
4.2. competences	Knowledge about: electrodynamics, quantum mechanics

5. Conditions/Infrastructure (if necessary)

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

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools. R5. The student/graduate critically evaluates scientific results and formulates reliable conclusions. R6. The student/graduate integrates knowledge across disciplines to address complex physical problems.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software. R5. Evaluates scientific literature and data with critical judgment. R6. Connects physics with related scientific and engineering domains.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently. R5. Performs independent investigations with critical awareness. R6. Integrates interdisciplinary approaches in research tasks.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
The open questions from the standard model	Systematic exposition - lecture. Examples	2 Hours
Hierarchy problem. Supersymmetries (SUSY). SUSY Algebra and SUSY Group.	Systematic exposition - lecture. Examples	5 Hours
Superfields formulation. Irreducible representation of SUSY. Chiral superfields and vector superfields.	Systematic exposition - lecture. Examples	5 Hours
Spontaneous SUSY breaking	Systematic exposition - lecture. Examples	4 Hours
Extradimensions	Systematic exposition - lecture. Examples	4 Hours

References:
1. S. Weinberg, The quantum theory of fields, Vol. III Cambridge University Press, 2005.
2. T. Morii, C. S. Lim and S. N. Mukherjee, The physics of Standard Model and beyond. World Scientific 2005

7.2 Tutorials	**Teaching techniques**	**Observations**
Aspects of grand unification theories (GUT). Magnetic monopoles.	Problem solving	4 Hours
Construction of supersymmetric Lagrangians.	Problem solving	4 Hours
The Minimal Supersymmetric Standard Model	Problem solving	4 Hours
Composite Higgs models: Technicolor, Higgs as Pseudo-Goldstone boson, LHC signatures	Problem solving	4 Hours
The role of string theories	Problem solving	4 Hours

References:
1. S. Weinberg, The quantum theory of fields, Vol. III Cambridge University Press, 2005.
2. H. Georgi, "The Future Of Grand Unification", Prog. Theor. Phys. Suppl. 170 (2007)
3. S. P. Martin, "A Supersymmetry Primer", arXiv:hep-ph/9709356.
4. R. Rattazzi, "Cargese lectures on extra dimensions", arXiv:hep-ph/0607055.
5. Barton Zwiebach, A first course in string theory, Cambridge University Press, 2009

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
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%
Tutorial	- Ability to use specific problem solving methods	Homeworks	40%

Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.

Date, 13.07.2025	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
Date of approval 15.07.2025		Head of department name and signature Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.212 Introduction to string theory

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title			Introduction to string theory				
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	

3. Total estimated time

3.1. Hours per week	4	3.2. Lectures	2	3.3. Tutorials/Practicals/Projects	2/0/0
3.4. Total hours per semester	40	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	20/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					30
Research in library, study of electronic resources, field research					15
Preparation for practicals/tutorials/projects/reports/homework					15
Tutorat					0
Other activities					0
3.7. Total hours of individual study					60
3.8. Total hours per semester					100
3.9. ECTS					4

4. Prerequisites (if necessary)

4.1. curriculum	Special Relativity and Quantum Mechanics
4.2. competences	Knowledge about: algebra, differential geometry, solving differential equations

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	videoprojector
5.2. for tutorials/practicals	videoprojector

6. Learning outcomes

Knowledge	R1. The student/graduate explains fundamental and advanced laws of physics and their applications. R2. The student/graduate derives and applies mathematical models to describe physical systems. R3. The student/graduate selects and uses appropriate analytical, numerical, and statistical methods. R4. The student/graduate solves problems in theoretical and computational physics with modern tools.
Skills	R1. Uses advanced principles of classical, quantum, and statistical physics. R2. Applies mathematical methods for modeling and solving physics problems. R3. Employs computational and numerical techniques for analysis and simulation. R4. Solves theoretical and applied problems using specialized software.

Responsibility and autonomy	R1. Presents scientific work clearly to both expert and general audiences. R2. Manages independent and collaborative research projects effectively. R3. Takes responsibility for applying suitable research methods. R4. Organizes and interprets data rigorously and efficiently.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Supersymmetry and supergravity - brief introduction. Intuitive things about String Theory.	Systematic exposition - lecture. Examples.	4 Hours
Electromagnetism and Gravitation in higher dimensions. The relativistic point particle. Relativistic strings. Nambu-Goto string action. Polyakov action.	Systematic exposition - lecture. Examples.	2 Hours
More on Gravitation in higher dimensions. Significance of the equations of motion of the relativistic string. Symmetries of the worldsheet.	Systematic exposition - lecture. Examples.	2 Hours
Relativistic quantum open strings. Strings as harmonic oscillators with transverse Virasoro operators. Constructing the space state; elements of string field theory.	Systematic exposition - lecture. Examples.	2 Hours
Relativistic quantum closed strings. Closed string Virasoro operators. Closed string space state. Graviton states. The dilaton and the Kalb-Ramond field.	Systematic exposition - lecture. Examples.	2 Hours
Dp- branes. Strings between parallel Dp and Dq branes. Intersecting D6-branes.	Systematic exposition - lecture. Examples.	2 Hours
String thermodynamics and black holes. Hagedorn temperature. String partition function. Black holes and entropy. Counting microstates of black holes.	Systematic exposition - lecture. Examples.	2 Hours
T duality of closed string. Left and Right movers. Spectrum of the compactified string. T duality as a full quantum symmetry. T duality of the open string. Wilson lines.	Systematic exposition - lecture. Examples.	1 Hour
Interacting open string and Riemann surfaces. Moduli spaces of Riemann surfaces. String worldsheets as Riemann surfaces. Veneziano amplitude.	Systematic exposition - lecture. Examples.	1 Hour
Type I and Type II superstrings. Ramond and Neveu-Schwarz sectors. Modular invariance	Systematic exposition - lecture. Examples.	2 Hours
References: Barton Zwiebach: "A first course in String Theory" J. Polchinski : "String Theory: Superstring theory and beyond", volume II		
7.2 Tutorials	**Teaching techniques**	**Observations**
Classical non-relativistic strings. Elements of Special Relativity. Lightcone coordinates.		4 Hours
Light cone classical relativistic strings. Mode expansions. Transverse Virasoro modes. Review of relativistic quantum point particle.		4 Hours
The string and D-branes charge. The Standard Model derived from String Theory.		8 Hours
Interacting open string and Riemann surfaces. Moduli spaces of Riemann surfaces. String worldsheets as Riemann surfaces. Veneziano amplitude.		4 Hours
References: Barton Zwiebach: "A first course in String Theory" J. Polchinski : "String Theory: Superstring theory and beyond", volume II		

8. 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.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity and coherence of exposition - Correct use of the methods/ physical models - The ability to give specific examples	written test	60%
Tutorial	- Ability to use specific problem solving methods	homeworks	40%
Minimal requirements for passing the exam	At least 50% of exam score and of homeworks.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025		

Date of approval	Head of department name and signature
15.07.2025	Lect. dr. Rozana ZUS

Syllabus

Academic year 2025/2026
DFC.213 Volunteering

1. Study program

1.1. University	University of Bucharest
1.2. Faculty	Faculty of Physics
1.3. Department	Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Theoretical and Computational Physics

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher							
2.3. Tutorials/Practicals instructor(s)							
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	verificare	2.7.Classification	

3. Total estimated time

3.1. Hours per week	0	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/0/0
3.4. Total hours per semester	0	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/0/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					13
Research in library, study of electronic resources, field research					6
Preparation for practicals/tutorials/projects/reports/homework					6
Tutorat					0
Other activities					0
3.7. Total hours of individual study					25
3.8. Total hours per semester					25
3.9. ECTS					1

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competences	

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R10. The student/graduate acquires civic competences.
Skills	R10. The student/graduate improves communication skills.
Responsibility and autonomy	R10. Shows spirit of initiative and entrepreneurship.

7. Contents

8. 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

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Minimal requirements for passing the exam	

Date,

13.07.2025

Teacher's
name and signature,

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

Date of approval

15.07.2025

Head of department
name and signature
Lect. dr. Rozana ZUS