Programul de studii: Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

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

Discipline obligatorii:

DI.101 Statistical Quantum Physics
DI.102 Interactions of the ionizing particles with matter
DI.103 Groups theory and applications in Physics
DI.104 Ethics and academic integrity
DI.105 Research activity practice
DI.108 Radiation sources, dosimetry, and radiological protection
DI.109 Medical and Nuclear Electronics
DI.201 Relativistic nuclear Physics. Anomal states and phase transitions in nuclear matter
DI.202 Elementary particles phenomenology. Elements of Cosmology and astroparticle Physics.
DI.206 Research activity practice
DI.207 Research activity and Dissertation thesis preparation

Discipline opţionale:

DO.106.1 Radionuclides, environmental radioactivity, and nuclear waste management
DO.106.2 Applications of Nuclear Physics in life sciences and medicine
DO.110.1 Models for nuclear structure, nuclear and photonuclear reactions
DO.110.2 Experimental physics of heavy-ions at low energies
DO.111.1 Detection methods in Physics of atom, nucleus, elementary particles, and Astrophysics
DO.111.2 Large experiments in Nuclear Physics, Particle Physics and Astrophysics
DO.203.1 Nuclear fission and fusion. Nuclear reactors and nuclear energetics
DO.203.2 Radioactive beams, nuclear bosonic condensation, and new types of nuclei
DO.204.1 Nuclear magnetic resonance. Physical principles and applications
DO.204.2 Atomic and molecular clusters
DO.208.1 Spectroscopic methods and techniques for investigation of the nuclear and subnuclear systems
DO.208.2 Properties of atomic and molecular systems. Experimental models and techniques
DO.209.1 Lasers, plasma, and acceleration methods. Experimental applications at ELI-NP
DO.209.2 Plasma physics in the study of nuclear, astrophysical, and cosmological processes

Discipline facultative:

DFC.107 Volunteering
DFC.112 Simulation codes in Nuclear Physics
DFC.113 Nuclear archaeology
DFC.114 Volunteering
DFC.205 Volunteering
DFC.210 Complements of nuclear and photonuclear reactions
DFC.211 Current experimental problems in Atomic and Nuclear Physics
DFC.212 Nuclear security
DFC.213 Volunteering

Syllabus

Academic year 2025/2026
DI.101 Statistical Quantum 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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Statistical Quantum 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	DA

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	30
Research in library, study of electronic resources, field research	30
Preparation for practicals/tutorials/projects/reports/homework	15
Tutorat	0
Other activities	47
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	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	
Skills	
Responsibility and autonomy	

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	1 Hour
Quantum entropy. Boltzmann-von Neumann formula. Physical interpretation. Principle of maximum entropy. Equilibrium distributions. Statistical operator in equilibrium. BoltzmannGibbs formula.	Systematic exposition - lecture. Examples	3 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	2 Hours
The indistinguishability of quantum particles. Occupations number representation. Pauli principle. Applications.	Systematic exposition - lecture. Examples	4 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

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 Interactions of the ionizing particles with matter

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Interactions of the ionizing particles with matter						
2.2. Teacher	Mihaela Parvu, Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Mihaela Parvu, Oana Ristea						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DA

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					44
Research in library, study of electronic resources, field research					18
Preparation for practicals/tutorials/projects/reports/homework					28
Tutorat					0
Other activities					4
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	Mathematical analysis, Algebra, Geometry, Equations of mathematical physics, Electricity, Atomic physics, Nuclear physics, Optics, Quantum physics, Statistical physics
4.2. competences	Programming languages, Physical data processing and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom (preferably, but not required, multimedia facilities)
5.2. for tutorials/practicals	Experimental setups from Nuclear Physics Laboratory, Dosimetry Laboratory, Computer Network (or individual laptops) Films obtained in the 81 cm bubble chamber / CERN exposed to a beam of pi- of 2.2 GeV / c at the accelerator of 28GeV Films obtained at the 2 m bubble chamber / CERN filled with hydrogen Films obtained at high pressure chamber - JINR-Dubna, filled with 3He exposed to beams of pi+ / _ at kinetic energies of 100, 120, 145 and 180 MeV

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R4. The student/graduate knows the fundamental concepts of dosimetry as well as the principles and rules of radiological protection. R5. The student/graduate has advanced knowledge of the behavior of radionuclides in the environment, as well as of the natural and anthropogenic processes that influence environmental radioactivity.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R4. The student/graduate applies and evaluates safety and radiological protection regulations, applicable in educational and research laboratories. R5. The student/graduate uses sampling, analysis, and data interpretation methods for radioactive contamination, including spectrometry and dosimetry techniques applied in environmental contexts.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R4. The student/graduate takes responsibility for complying with radiological protection norms and ethical standards in multidisciplinary teams. R5. The student/graduate complies with safety and radiation protection regulations, taking responsibility for risk assessment and the protection of the environment and public health.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Sources of radiation and radioactivity: a) Primary cosmic rays: component of charged particles, neutrinos, gamma, characteristic X-rays, their possible origins, role models; b) Cosmic-secondary rays; interactions with the atmosphere; c) Terrestrial radiation (natural and artificial); d) Sources of geo-terrestrial nature	Systematic exposition - lecture. Examples	4 Hours

I. Particle interactions with atomic electrons a) Electronic energy losses of heavy charged particles - heavy particles and ions: effective sections, stopping power depending on the energy domain, knock-on electrons (electrons delta); Bethe-Bloch equation, energy losses in thin layers of material; fluctuations in energy losses, the case of mixtures and compounds, ionization efficiency, multiple scattering at small angles, the Cerenkov effect and the transition radiation b) Interactions of photons and electrons in the matter: radiation length, energy losses for electrons, critical energy; photon energy losses (Raylegh, Thomson, Compton scattering, photoelectric effect), bremsstrahlung and pair production at high energies, electromagnetic cascade production at high energies c) Energy losses of muons d) Energy losses of neutrinos	Systematic exposition - lecture. Examples	14 Hours
II. Interactions with nuclei a) Interactions of heavy charged particles - Lindhard model b) Neutron interactions c) Photonuclear and electronuclear interactions at high energies	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	6 Hours
III. Specific detection principles according to the type of particles and the energy field considered	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours

References:

1) M. Nastasi, J. Mayer, J. Hirvonen, Ion-solid interactions: fundamentals and applications, Cambridge University Press 20041.

2) G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000

3) W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003).

4) Claus Grupen, Astroparticle Physics, Springer-Verlag Berlin Heidelberg 2005

5) Particle Data Group, http://pdg.lbl.gov (27. Passage particles through Matter))

6) I. Lazanu, Oana Ristea, INTERACTIILE PARTICULELOR CU MATERIA - Caiet de laborator si aplicatii numerice - versiune electronica

7.3 Practicals	**Teaching techniques**	**Observations**
Measurement of cosmic rays using scintillator detectors and calculation of the spectrum	Guided practical activity	2 Hours
Experimental study of the interactions of alpha particles, electrons, neutrons, and gamma rays in various types of detectors	Guided practical activity	10 Hours
Calculation of energy losses for high-energy particles (electrons, positrons, and delta electrons) using data obtained from the bubble chamber and streamer chamber - experimental determination of the Bethe-Bloch equation	Guided practical activity	4 Hours
Monte Carlo simulations of ion interactions in various media (electronic, nuclear, and phonon contributions) using specific codes (e.g., SRIM, FLUKA)	Guided practical activity	4 Hours
Numerical applications	Problem solving	8 Hours

References:

I. Lazanu, Oana Ristea, INTERACTIILE PARTICULELOR CU MATERIA - Caiet de laborator si aplicatii numerice - versiune electronica

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	- coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyse specific examples	Writen examination	70%
Tutorial	- ability to use specific problem solving methods - ability to analyse the results	Homeworks/writen tests	10%
Practical	- ability to use specific experimental methods/apparatus - ability to perform/design specific experiments - ability to present and discuss the results		20%
Minimal requirements for passing the exam	Correct understanding of the concepts and phenomena, the ability to work with them and obtain accurate numerical results on topics imposed. Carrying out all the activities during the semester Obtaining note 5 by summing the points obtained at the activities during the course and examination, according to the weights specified		

Date,
13.07.2025

Teacher's
name and signature,
Mihaela Parvu, Oana Ristea

Practicals/Tutorials/Project instructor(s),
name and signature
Mihaela Parvu, Oana Ristea

Date of approval
15.07.2025

Head of department
name and signature
Lect. dr. Sanda VOINEA

Syllabus

Academic year 2025/2026
DI.103 Groups theory and applications in Physics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Groups theory and applications in Physics						
2.2. Teacher	Conf.dr. Vasile Bercu, Conf.dr. Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Conf.dr. Vasile Bercu, Conf.dr. Oana Ristea						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DA

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					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	Linear algebra, Quantum mechanics
4.2. competences	Knowledge about: mechanics, atomic physics, solid state physics, nuclear and particle 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 deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Applications in atomic and molecular physics: Elements, operations, and point groups of symmetry	Systematic exposition - lecture. Examples	2 Hours
Point group theory of symmetry and the properties of atomic and molecular systems	Systematic exposition - lecture. Examples	2 Hours
Symmetry and the interactions of atomic orbitals Valence bond theory and hybridization of atomic orbitals	Systematic exposition - lecture. Examples	2 Hours
Applications in Nuclear Physics: Isospin in Nuclear Physics, an example of the SU(2) group. Iospin multiplets. Isospin in nucleon-nucleon and pion-nucleon interactions. Relative decay rates and cross-sections	Systematic exposition - lecture. Examples	3 Hours
Quark model and SU(3) symmetry. Isospin and strangeness of hadrons. SU(3) raising and lowering operators. Combining SU(3) states: 2 quarks, adding the 3rd quark, quark-antiquark states	Systematic exposition - lecture. Examples	5 Hours

References:

1. F. Halzen, A. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics. Wiley, 1991.
2. I. Lazanu, Spectroscopia hadronilor, Ed. Univ. din Bucuresti, 1998
3. S. Wong, Introductory Nuclear Physics, Wiley, 1998
4. Peter W. Atkins, Ronald S. Friedman, Molecular Quantum Mechanics, Oxford University Press, 2010
5. Robert R. Carter, Molecular symmetry and group theory, John Wiley and Sons,Inc. 1998

7.2 Tutorials	Teaching techniques	Observations
Symmetry in atomic and molecular systems: the role of point group theory and orbital interactions	Problem solving	2 Hours
Valence bond theory and orbital hybridization in atomic and molecular physics	Problem solving	2 Hours
Applications of symmetry and group theory in understanding atomic and molecular structures	Problem solving	2 Hours
Isospin aplications	Problem solving	2 Hours
Decay rates and cross-section in nucleon/pion-nucleon scatterings - examples	Problem solving	3 Hours
Hadron (meson and baryon masses) calculations	Problem solving	3 Hours

References:

1. Tatiana Angelescu, Alexandru Mihul, Probleme de Fizica particulelor elementare la energii inalte, Editura Tehnica, Bucuresti, 1971
2. Ahmad Kamal, 1000 Solved Problems in Modern Physics, Springer, 2010
3. Lim Yung-Kuo, Problems and solutions on atomic, nuclear and particle physics, World Scientific, 2000
4. Peter W. Atkins, Ronald S. Friedman, Molecular Quantum Mechanics, Oxford University Press, 2010
5. Robert R. Carter, Molecular symmetry and group theory, John Wiley and Sons,Inc. 1998

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	70%
Tutorial	- Ability to use specific problem solving methods	Homeworks	30%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale) At least 50% of exam score. Requirements for mark 10 (10 points scale) Correct solutions to all subjects in final exam. Correct solutions to homework problems.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf.dr. Vasile Bercu, Conf.dr. Oana Ristea	Conf.dr. Vasile Bercu, Conf.dr. Oana Ristea

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

Syllabus

Academic year 2025/2026
DI.104 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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

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	DS

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	R10. The student/graduate should know the norms and ethical principles regarding scientific research in the field, as well as develop a culture of responsibility in intellectual work.
Skills	R10. The student/graduate should assimilate explicit norms (normative texts) or implicit ones (customs, practices) that regulate academic and research conduct in the field.
Responsibility and autonomy	R10. The student/graduate should demonstrate solidarity, responsiveness, and support for strengthening academic integrity.

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.105 Research activity practice

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Research activity practice						
2.2. Teacher	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu						
2.3. Tutorials/Practicals instructor(s)	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	project assessment	2.7.Classification	DA

3. Total estimated time

3.1. Hours per week	2	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	28	3.5. Lectures	0	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					24
Research in library, study of electronic resources, field research					12
Preparation for practicals/tutorials/projects/reports/homework					11
Tutorat					0
Other activities					0
3.7. Total hours of individual study					47
3.8. Total hours per semester					75
3.9. ECTS					3

4. Prerequisites (if necessary)

4.1. curriculum	Completion of courses from the first and second year curriculum
4.2. competences	Knowledge of mathematics, physics, programming languages and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology. R10. The student/graduate should know the norms and ethical principles regarding scientific research in the field, as well as develop a culture of responsibility in intellectual work. R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field. R10. The student/graduate should assimilate explicit norms (normative texts) or implicit ones (customs, practices) that regulate academic and research conduct in the field. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

Responsibility and autonomy	R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community. R10. The student/graduate should demonstrate solidarity, responsiveness, and support for strengthening academic integrity. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

7. Contents

7.3 Practicals	Teaching techniques	Observations
In accordance with the research topic chosen for the practice. The topics will lead to the definition of dissertation topics in accordance with the existing proposals.		1 Hour
Research topics (theoretical and experimental approaches specific to the fields of atomic and nuclear physics): (Coordinator: Prof.univ.dr. Mihaela SIN, Dr. Dan Mihai Filipescu) 1) Calculation of cross sections for neutron-induced reactions on plutonium isotopes (238Pu-242Pu) in the energy range 10 keV – 30 MeV 2) Calculation of the photo-fission cross sections for 230Th, 232Th in the energy range 3 - 30 MeV 3) Comparative analysis of the photo absorption sections calculated with the gamma force functions included in RIPL (Reference Library of input parameters) in the case of actinides 4) Modeling of the emission of prompt neutrons and prompt gamma quanta in nuclear fission 5) Investigating mass, charge, and kinetic energy distributions for fission fragments and initial nucle-ar fission products 6) The study of the periodicity of the nuclear prop-erties of radionuclide 7) Even-odd effects in nuclear fission These re-search topics require high-performance computing equipment (computer network and possibilities to store and access nuclear databases). They can be provided by the computing laboratories of the department.		4 Hours
(Coordinator: Conf.univ.dr. Vasile BERCU) 8) The study of free radicals generated by ionizing radiation 9) Studies in archaeophysics 10) Studies of paramagnetic ions in different systems of opto-electronic interest		4 Hours

(Coordinator: Conf.univ.dr. Oana RISTEA) 11) Study of radiation interaction with matter using GEANT4 12) Analysis of the constructive parameters of segmented electromagnetic calorimeters using GEANT4 13) Study of Coulomb interaction in relativistic nuclear collisions 14) Determination of thermal freezing parameters from the analysis of transverse momentum spectra using the ”blast-wave” model 15) Analysis of chemical freezing parameters using THERMUS model 16) Investigating the properties of hot, dense nuclear matter in relativistic nuclear collisions in the BRAHMS and CBM experiments 17) Conditions for formation and experimental signals of phases and phase transitions in hot dense nuclear matter 18) Experimental methods in nuclear physics, elementary particle physics and astroparticle physics		4 Hours
(Coordinator: Lect.univ.dr. Marius CĂLIN) 19) Obtaining dosimetric maps of the areas in Bucharest located in the vicinity of the CETs 20) The influence of the radiation dose absorbed by some seeds on their further evolution 21) Analysis by high-resolution gamma spectroscopy of some environmental samples (soil, vegetation, surface water) 22) Determination of the radon concentration in the buildings and its dependence on the age, the degree of damage, the structure of the walls (brick, concrete, wood), position on the city map, the degree of ventilation of the rooms 23) Application of simulation codes (FLUKA) to obtain a map of doses possibly present around given radioactive sources (emitting only one type of radiation or several types) 24) Using simulation codes for various experiments in Nuclear Physics, Particle Physics and Astroparticle Physics 25) Nuclear archaeology		4 Hours
(Coordinator: Lect. Dr. Mihaela PÂRVU, Prof. Dr. Ionel LAZANU) 26) Radioactive background studies in underground experiments for rare processes 27) Studies related to transient processes at the interactions of incident particles (neutrinos, muons, mesons) in materials used as detectors in particle and astroparticle physics (gaseous, liquid and solid argon, xenon, semiconductors) 28) Mechanisms of production of the isotope Ar-39 in Ar-40 29) Physics of solar neutrinos and neutrinos from supernovae 30) Physical processes and reaction channels for leptons above/beyond the Standard Model 31) Using passive detectors in radioactive background determinations		4 Hours

(Coordinator: Lect.univ.dr. Alecsandru Vladimir CHIROȘCA) 32) Dosimetry and radiation detection; modeling of detection parameters for all types of radiation 33) Neutron dosimetry and applications 34) Radiation transport modeling using the GEANT and Fluka codes 35) Dosimetry in radiation therapy at linear accelerators (GEANT, Gamos) 36) Statistical data processing (Python, ROOT) 37) Microcontrollers and IoT 38) The use of artificial intelligence systems in data processing 39) Modeling of radiation field production processes in high power lasers (1PW). Numerical modeling and PIC (Particle In Cell)		3 Hours
(Coordinator: Lect. dr. Radu Alin VASILACHE) 40) Measuring doses in Ultra High Dose Rate (UHDR) beams. Recombination measurements in ion chambers and models for the recombination at UHDR 41) Space dosimetry. Detectors for dose measurements in complex radiation fields similar to the interplanetary galactiv cosmic radiation 42) Internal dosimetry using whole body counters. Design of novel whole body counters 43) OSL dosimetry for personnel and area measurements. The design of the algorithms for complex field dosimetry using BeOSL dosimeters 44) High and medium resolution systems for the assay and sorting of radioactive waste. The design of automated systems for radioactive waste measurements 45) High resolution gamma spectroscopy for TL and OSL dating. The determination of annual doses in various soil samples.		4 Hours

References:
It is established by the internship coordinator, in accordance with the field of activity and the chosen topics.

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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in modern technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (University of Oxford https://www.ox.ac.uk/admissions/undergraduate/courses-listing?wssl=1, University of Parma http://www.difest.unipr.it/it/didattica/laurea-triennale-fisica/calendario-didattico, University of Padua, http://en.didattica.unipd.it/didattica/2015/SC1158/2014). The content of the discipline is according to the requirements for employment in research institutes in physics and materials science and in education (under the law).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark

Minimal requirements for passing the exam	Minimal requirements for passing the exam Requirements for mark 5 (10 points scale) • Mandatory attendance at all research activities Requirements for mark 10 (10 points scale) Experimental skills, well-argued knowledge and corect use of specific experimental techniques • Demonstrated ability to analyze phenomena and processes • Personal approach and interpretation

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu

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

Syllabus

Academic year 2025/2026

DI.108 Radiation sources, dosimetry, and radiological protection

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Radiation sources, dosimetry, and radiological protection						
2.2. Teacher	Lect. Dr. Marius CĂLIN						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Marius CĂLIN						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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	Mathematical analysis, Algebra, Geometry, The equations of mathematical physics, Electricity, Atomic Physics, Nuclear Physics, Optics, Quantum Physics, Statistical Physics
4.2. competences	Programming languages, Processing of physical data and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Lecture hall (preferred, but not mandatory, multimedia equipment)
5.2. for tutorials/practicals	The experimental modules from the Nuclear Physics Laboratory, the Dosimetry Laboratory, the Computer Network (or individual laptops)

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R4. The student/graduate knows the fundamental concepts of dosimetry as well as the principles and rules of radiological protection. R5. The student/graduate has advanced knowledge of the behavior of radionuclides in the environment, as well as of the natural and anthropogenic processes that influence environmental radioactivity. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R4. The student/graduate applies and evaluates safety and radiological protection regulations, applicable in educational and research laboratories. R5. The student/graduate uses sampling, analysis, and data interpretation methods for radioactive contamination, including spectrometry and dosimetry techniques applied in environmental contexts. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R4. The student/graduate takes responsibility for complying with radiological protection norms and ethical standards in multidisciplinary teams. R5. The student/graduate complies with safety and radiation protection regulations, taking responsibility for risk assessment and the protection of the environment and public health. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Nuclear radiation Radiation field and radiation sources Summary of the main mechanisms of interaction of radiation with matter (interactions with atomic electrons, with the nucleus, with the nuclear field): a) charged particles: excitation, ionization, radiative energy loss – comparative analysis between heavy and light charged particles; b) neutron interactions; c) photon interactions: Rayleigh, Thomson, Compton scattering, photoelectric effect, pair production Characteristic quantities: energy loss per unit range, range, LET, Bragg curve, X-ray and gamma attenuation: linear and mass attenuation coefficient	Systematic exposition - lecture. Examples	4 Hours
Radiation detection Principles of radiation protection; Specific aspects of shielding. Quantities and dosimetric units for radiation protection (KERMA, absorbed dose, exposure, dose equivalent, effective dose)	Systematic exposition - lecture. Examples Case studies	14 Hours

Applications: a) Biological effects of radiation; in vivo and in vitro dose response; clustered destructions b) Principles of methods of investigation and treatment with radiation c) Dosimetry at high energy accelerators and space missions	Systematic exposition - lecture. Examples	10 Hours

References:

1) G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000
2) W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003).
3) Daniel Cussol, Nuclear Physics and Hadrontherapy,
4) Malte C. Frese s.al., Int J Radiation Oncol. Biol. Phys, Vol. 83, No. 1, pp. 442e450, 2012
5) IAEA-TECDOC-1560, Dose Reporting in Ion Beam Therapy, 2007
6) IAEA, Jointly sponsored by the IAEA and ICRU Technical Reports Series 461
7) M. Oncescu, Dozimetria şi ecranarea radiaţiilor Roentgen şi gamma, Ed. Academiei, 1992
8) T. Angelescu s. al., 177 de probleme de dozimetrie, Ed. Ars Docendi
9) A. Jipa, M. Călin, A. Chiroşca, Probleme de dozimetrie, surse de radiaţii şi radioprotecţie – versiune electronică

7.3 Practicals	**Teaching techniques**	**Observations**
Types of dosimeters used for charged particles and neutrons	Guided practical work	4 Hours
Studies for the range of charged particles in different environments	Guided practical work	2 Hours
Solving problems and numerical applications	Solving problems	8 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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in physics and modern technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad. The content of the discipline is in accordance with the employment requirements in research institutes in nuclear physics and engineering and medical laboratories that use nuclear methods in investigation and treatment (under the law).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity, coherence and conciseness of presentation; - Correct use of calculation models, formulas and relationships; - The ability to exemplify; - In-depth application of knowledge	oral examination	70%
Practical	- Knowledge and use of experimental techniques; - Interpretation of the results;	Laboratory colloquim	30%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale) • Performing all practical activities during the semester • Obtaining grade 5 by adding up the points obtained for the activities during the course and the exam, in accordance with the specified weight		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Marius CĂLIN	Lect. Dr. Marius CĂLIN

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

Syllabus

Academic year 2025/2026
DI.109 Medical and Nuclear Electronics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Medical and Nuclear Electronics						
2.2. Teacher	Lect. Dr. Radu Alin Vasilache						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Radu Alin Vasilache						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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	Study of the course Interactions of the ionizing particles with matter Interacţiile radiaţiilor ionizante cu materia, Methods of Detection, Special Relativity Theory, Quantum Physics
4.2. competences	Knowledge on the use of nuclear apparatus, data analysis and processing, identifying sources of information

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Digital videoprojector / HD display
5.2. for tutorials/practicals	Laboratory apparatus: HV sources, signal generators, oscilloscopes, electrometers, multichannel analyzers, photomultiplier assembly, NIM amplifiers, NIM timer / scaler, NIM SCA, NIM Bin, computer.

6. Learning outcomes

Knowledge	R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields.
Skills	R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research).
Responsibility and autonomy	R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations

Particle accelerators for nuclear and mecial physics. Overview of the development of accelerators. The direct voltage accelerator. Cockroft - walton cascade generator, Marx generator, Van de Graaf accelerator. general principles of LINAC, cyclotron, microtron, betatron and synchrotron	Systematic exposition. Lecture. Examples	4 Hours
The LINAC and its medical applications. Principles of electron acceleration. waves and modes in guides and cavities. Electron buunching. Microwave generation and transmission. Electron sources. Beam transport and beam optics. Beam shaping, Beam monitors and dosimetry controlsystems. properties of LINAC beams. Ancillary systems.	Systematic exposition. Lecture. Examples	6 Hours
Proton and heavy ion accelerators and their medical applications. Circular accelerators for proton therapy: the cyclotron and the sychrocyclotron, the DWAs. Types of accelerators for heavy ion therapy: synchrotrons and cyclotrons for carbon ion therapy. Linacs for carbon-ion therapy. New developments for particle therapy: laser based accelerators and fixed field alternating gradient particle accelerators. Beam extraction. Beam transport.	Systematic exposition. Lecture. Examples	4 Hours
Dosimetry for particle accelerators. Ionisation chambers: physical and operational principles. Types of chambers. Electrometers, cables and connectors. Determination of charge produced in the chamber. Correction factors to be considered for the measurements. Solid state detectors: diode and MOSFET detectors. Diamond detectors. Equipment for 2D and 3D dosimetry. Equipment for absolute and relative dosimetry.	Systematic exposition. Lecture. Examples	4 Hours
The cyclotron accelerator and its use in medical isotope production. Principles of cyclotron operation. Types of cyclotrons used in medical isotope production. Targets. Ancillary equipment: hot cells and dispensers	Systematic exposition. Lecture. Examples	2 Hours
Equipment for medical diagnostic imaging. SPECT imaging: principles and equipment. PET imaging: principles and equipment. Computed tomography scanners. Equipment for hot rooms.	Systematic exposition. Lecture. Examples	4 Hours
Electronic instrumentation for calorimetric measurements in particle physics. Front-end signal electronics. Trigger processors. Timing electronics and time measurement. Multichannel scaler and multichannel analysers for energy measurements and time stamp measurements. Operation in magnetic fields. Radiation damage for detectors and electronics.	Systematic exposition. Lecture. Examples	2 Hours
Amplification and processing of analog signals. Preamplifiers and amplifiers for nuclear physics. Filtering. Pile-up effects. Fast amplifiers. Pulse formation. Coincidence circuits and time – amplitude analysis circuits.	Systematic exposition. Lecture. Examples	2 Hours

References:

1. Edmund Wilson, An Introduction to Particle Accelerators, Oxford University Press, 2006.
2. Klaus Wille, The Physics of Particle Accelerators, Oxford University Press, 2005
3. W. P. Mayles, A. E. Nahum, J. C. Rosenwald (eds.), Handbook of Radiotherapy Physics, CRC Press, 2022
4. E. B. Podgorsak (ed.), Radiation Oncology Physics: A Handbook for Teachers and Students, International Atomic Energy Agency, 2005
5. J.-J. Samueli, J. Pigneret, A. Sarazin, Instrumentaţia electronică în fizica nucleară (Măsurări de timp şi energie), Ed. Tehnică Bucureşti, 1972
6. Richard Wigman, Calorimetry. Energy Measurements in Particle Physics, Oxford University Press 2008

7.3 Practicals	**Teaching techniques**	**Observations**
Electronic circuits for analog signal processing.	Theoretical exercises and practical activity	2 Hours

Digital instrumentation for gamma spectroscopy	Theoretical exercises and practical activity	2 Hours
Photomultiplier tubes	Theoretical exercises and practical activity	2 Hours
Measurement of charge with different types of circuits and detectors	Theoretical exercises and practical activity	2 Hours
Ion chambers and electrometers for radiotherapy	Theoretical exercises and practical activity	2 Hours
Electrical and radiological safety measures. The physiological effects of ionising radiation and electric shocks. Methods of protection against exposure radiation and against electric shocks.	Lecture. Examples. Theoretical exercises.	2 Hours
The NIM and VME standards	Lecture. Examples. Theoretical exercises.	2 Hours

References:

1. E. B. Podgorsak (ed.), Radiation Oncology Physics: A Handbook for Teachers and Students, International Atomic Energy Agency, 2005
2.
J.-J. Samueli, J. Pigneret, A. Sarazin, Instrumentaţia electronică în fizica nucleară (Măsurări de timp şi energie), Ed. Tehnică Bucureşti, 1972

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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in medicine and medical research, the professors of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (Oxford University, International Atomic Energy Agency, European Federation of Organisations for Medical Physics, European Association for Nuclear Medicine, etc.). The content of the discipline is in accordance with the requirements for employment in research institutes and medical physics (radiotherapy and nuclear medicine) laboratories.

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	Oral exam and assessment	70%
Practical	- Knowledge and use of experimental techniques - Interpretation of the results - Problem solving	Laboratory colloquium	30%
Minimal requirements for passing the exam	Completion of all laboratory work and grade 5 in the laboratory and tutorials colloquium The correct exposure of the indicated subjects at least at qualitative level to obtain a score of 5 in the final exam.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Radu Alin Vasilache	Lect. Dr. Radu Alin Vasilache

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

Syllabus

Academic year 2025/2026

DI.201 Relativistic nuclear Physics. Anomal states and phase transitions in nuclear matter

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Relativistic nuclear Physics. Anomal states and phase transitions in nuclear matter						
2.2. Teacher	Conf. dr. Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Conf. dr. Oana Ristea						
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DA

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	72
Research in library, study of electronic resources, field research	36
Preparation for practicals/tutorials/projects/reports/homework	36
Tutorat	0
Other activities	0
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	Nuclear Physics and Elementary Particles, Astrophysics, Quantum mechanics and quantum physics, Thermodynamics and statistical physics, Electrodynamics and relativity theory, Experimental methods in nuclear physics
4.2. competences	Knowledge of mathematics, programming languages and numerical methods, use of simulation codes and software tools for data analysis/processing

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia infrastructure (PC, videoprojector, internet conection)
5.2. for tutorials/practicals	Computers Software for fitting experimental data and graphics (Minuit, origin, grafmatica) Different simulation codes (HIJING, AMPT, GEANT, UrQMD, PITHYA etc.) Films obtained in 2m streamer chamber at JINR-Dubna Experimental database of the BRAHMS collaboration from RHIC-BNL Database of CBM Collaboration from FAIR-GSI

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Introduction to Relativistic Nuclear Physics. Definitions. Terms appearance , development stages, specific physical quantities Experimental methods in relativistic nuclear physics. Accelerator systems, detection systems. Large laboratories and major experiments	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Physical quantities with dynamic significance. Participants –spectators picture. Rapidity and pseudorapidity, associated distributions and physical significance, multiplicities and multiplicity distributions , associated moments, cross sections, nucleon participants, momentum spectra and energy spectra , angular distributions, spatial and temporal characteristics of the particle source. Evolution of a relativistic nuclear collisions, evolution stages, observables, parameters.	Systematic exposition - lecture. Examples	4 Hours
Modeling the dynamics of relativistic nuclear collisions. The complexity of interactions and diversity of concepts. The need for modeling and ranking models. Classic models. Models based on Vlasov equation, Vlasov - Uenling - Uhlenbeck equation and Boltzmann equation. Intranuclear cascade models. Thermodynamic models. Hydrodynamic models. Hybrid models etc..	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Conditions for the formation of anomalous states of matter and for the occurrence of phase transitions in nuclear matter. Types of anomalous states of matter and types of nuclear matter phases. The phase diagram of nuclear matter. Phase transition to the quark-gluon plasma (quarks and gluons properties, asymptotic freedom, the interaction potential between quarks). QCD lattice.	Systematic exposition - lecture. Heuristic conversation. Examples	4 Hours
Connections with cosmological processes. Big Bang. Evolution scenarios. Evolution stages retrievable through relativistic nuclear collisions. Quark gluon plasma and hadronization process.	Systematic exposition – lecture. Critical analysis. Examples	2 Hours

Experimental signals of quark-gluon plasma production. Suppression of high transverse momentum particles. Parton distribution functions. Fragmentation functions. Nuclear effects (initial and final state effects). Experimental results.	Systematic exposition – lecture. Critical analysis. Examples	2 Hours
Production of heavy quarks (quarkonia). The interaction potential between two quarks. Debye shielding. Sequential suppression of heavy quark bound states in the quark-gluon plasma and recombination process. Nuclear effects. Experimental results.	Systematic exposition – lecture. Critical analysis. Examples	2 Hours
Electromagnetic signals. Production of photons and dileptons. Strangeness production Collective flow (anisotropic flow and transverse)	Systematic exposition – lecture. Critical analysis. Examples	4 Hours
Experimental results obtained in nuclear collisions at relativistic and ultrarelativistic energies. Multiplicities and multiplicity distributions. Impact parameter and collision centrality. Glauber model. Rapidity and rapidity distributions. The Landau vs Bjorken models. Estimate of energy density based on Bjorken model. Chemical freeze-out stage. Experimental parameters. Statistical models. Kinetic (thermal) freeze-out stage. Experimental parameters. Blast-wave model.	Systematic exposition – lecture. Critical analysis. Examples	2 Hours

References:

1. A Das and T. Ferbel, Introduction to Nuclear and Particle Physics, World Scientific, Second edition, 2005
2. Ray Hagedorn – Relativistic Kynematics, Academic Press, 1968
3. B.R.Martin – Statistics for Physicists, Plenum Press, 1971
4. C.Wong – Relativistic Heavy Ion Collisions, World Scientific, 1996
5. Ramona Vogt – Ultrarelativistic Heavy Ion Collisions, Elsevier Publishing, 2007
6. Al.Jipa, C.Beşliu – Elemente de Fizică nucleară relativistă. Note de curs, Editura Universităţii din Bucureşti, 2002
7. C.Beşliu, Al.Jipa – Elemente de Fizică nucleară relativistă. Note de seminar şi îndrumător de laborator, Editura Universităţii din Bucureşti, 1999
8. Al.Jipa – Culegere de probleme de Fizică nucleară relativistă (formă electronică)
9. The Physics of the Quark-Gluon Plasma, S. Sarkar et all, Springer Verlag, 2010
10. Quark-Gluon Plasma 3, R. C. Hwa, X. N. Wang, World Scientific, 2004

7.3 Practicals	**Teaching techniques**	**Observations**
Study of the rapidity/pseudorapidity and rapidity/pseudorapidity distributions for different nucleus-nucleus collisions at relativistic and ultrarelativistic energies	Guided practical work	4 Hours
Determination of multiplicities and multiplicity distributions in different nucleus-nucleus collisions at relativistic and ultrarelativistic energies	Guided practical work	4 Hours
Determination of the number of participating nucleons from various nucleus-nucleus collisions at relativistic and ultrarelativistic energies	Guided practical work	2 Hours
Determination of apparent temperature from the analysis of transverse momentum spectra of produced particles in the collisions	Guided practical work	4 Hours
Determination of flow velocities and freeze-out temperatures using the blast wave model	Guided practical work	2 Hours
Study of the anisotropic flow coefficients (v2,v3) în simulated heavy-ion collisions	Guided practical work	4 Hours
Study of the Coulomb interaction în relativistic heavy-ion collisions using the pion ratios	Guided practical work	2 Hours
Relativistic kinematics notions. Solving specific problems	Guided practical work	6 Hours

References: Al.Jipa – Culegere de probleme de Fizică nucleară relativistă (formă electronică) https://root.cern.ch/

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 forms/develops some theoretical and/or practical competences and abilities which are important/fundamental/something else for a graduate student in the field of modern 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 or the European Union străinătate (University of Oxford https://www.ox.ac.uk/admissions/undergraduate/courses-listing?wssl=1, Universityof Parma http://www.difest.unipr.it/it/didattica/laurea-triennale-fisica/calendario-didattico, Universitatea Padova, http://en.didattica.unipd.it/didattica/2015/SC1158/2014). The contents are in line with the requirements/expectations of the main employers of the graduates (industry, research, 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/analyse specific examples	Oral examination	70%
Practical	- ability to analyse the experimental and simulation codes results - data processing and analysis - ability to present and discuss the results - ability to use specific problem solving methods - correct use of physical methods/models	Lab reports	30%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale) Basic notions from the course content, meeting the requirements of the laboratory and verification of learning laboratory requirements Requirements for mark 10 (10 points scale) Good knowledge of all the topics from the course content		

Date,
13.07.2025

Teacher's
name and signature,
Conf. dr. Oana Ristea

Practicals/Tutorials/Project instructor(s),
name and signature
Conf. dr. Oana Ristea

Date of approval
15.07.2025

Head of department
name and signature
Lect. dr. Sanda VOINEA

Syllabus

Academic year 2025/2026
DI.202 Elementary particles phenomenology. Elements of Cosmology and astroparticle Physics.

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Elementary particles phenomenology. Elements of Cosmology and astroparticle Physics.						
2.2. Teacher	Mihaela Parvu, Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Mihaela Parvu, Oana Ristea						
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DA

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					72
Research in library, study of electronic resources, field research					36
Preparation for practicals/tutorials/projects/reports/homework					36
Tutorat					0
Other activities					0
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	Higher mathematics, Quantum mechanics, Statistical physics, Atomic physics, Nuclear physics and elementary particles
4.2. competences	Programming languages, Physical data processing and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom (preferably, but not required, multimedia facilities)
5.2. for tutorials/practicals	Experimental setups from Nuclear Physics Laboratory, Dosimetry Laboratory, Computer Network (or individual laptops) Films obtained in the 81 cm bubble chamber / CERN exposed to a beam of pion- of 2.2 GeV / c at the accelerator of 28GeV Films obtained at the 2 m bubble chamber / CERN filled with hydrogen Films obtained at high pressure chamber - JINR-Dubna, filled with 3He exposed to pions + / _ beams at kinetic energies of 100, 120, 145 and 180 MeV Measurements of galaxies obtained with the radio telescope of Univ. Seattle and their emission and / or absorption spectra in visible

6. Learning outcomes

Knowledge	R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R6. The student/graduate understands the fundamental concepts of modern cosmology and astrophysics, including the structure and evolution of the Universe, galaxy formation, and primordial nucleosynthesis. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.
Skills	R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R6. The student/graduate analyzes and interprets data from observations and numerical simulations, using theoretical models to describe cosmological and astrophysical phenomena. R7. The student/graduate uses computing codes or software packages for research topics and specific applications.
Responsibility and autonomy	R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R6. The student/graduate demonstrates initiative and autonomy in exploring topics in cosmology and astrophysics, contributing to research or science outreach activities, and integrating acquired knowledge in interdisciplinary contexts. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Elements of relativistic kinematics Properties and interactions of elementary particles: Forces, Elementary particles, Introduction of the antiparticle concept, Quantum numbers (baryon number, lepton numbers, strangeness, isospin; other specific tasks), Gell-Mann Nishijima relation, Production and disintegration of resonances, Spin determination, Violations of quantum numbers	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Symmetries: Phenomenological aspects, Fundamentals of the quark model, Quarks content for mesons and baryons. Color, color symmetry, extension of the quark pattern. The hidden symmetries. Experimental confirmations. Discrete symmetries.	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours

Formulation of the standard model: The fundamental constituents: quarks, gluons, leptons; The concepts of valence quarks and "sea quarks" for hadrons. Mechanisms. Gauge. Dynamics of gauge particles. Spontaneous breaking of symmetry Comparison of the standard model with the experimental data. Physics beyond the standard model. Reproduction of the conditions of the Universe in the early Universe of the big explosion (big-bang). New acceleration facilities	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	6 Hours
The expansionist universe: Observational aspects about the Universe, Newtonian Cosmology, Elements of curvilinear geometry.	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
Einstein's Equations, Cosmic Dynamics, Elements of Primordial Nucleosynthesis, Phase Transitions in the Early Universe. Planck era. Estimates of cosmic parameters. Scenarios of phase transitions. Baryogenesis and asymmetry of matter-antimatter for the universe. Other aspects.	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	7 Hours
Cosmic particles: Neutrinos. Gravitational waves (Detection; experiments). Classic black holes and quantum aspects. Hawking radiation. Dark matter and dark energy of the universe: Sources of dark matter. Searches, experiments, results. New ideas	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	3 Hours

References:

Bibliography:
F.E. Close An introduction to quarks and partons, Academic Press 1979
A. Das, T. Ferbel, Introduction to nuclear and particle physics, World Scientic 2005
D. Griffits, Introduction to elementary particles, JohnWilley and Sons 1987
K. Gottfried, V. Weisskopf, Subnuclear Phenomena (in Concepts of Particle Physics), Oxford University Press 1984
I. Lazanu, Paricule elementare, astroparticule si elemente ale universului timpuriu (aplicatii numerice si probleme rezolvate), Ed. Univ. din Bucuresti 2002
Ray Hagedorn - Relativistic Kynematics, Academic Press, 1968
B.R.Martin - Statistics for Physicists, Plenum Press, 1971
Claus Grupen, Astroparticle Physics, Springer 2005
R. D. Peccei - Physics at the interface of particle physics and cosmology – hep-ph/9808418
Ian R. Kenyon - General relativity, Oxford Univ. Press 1990
Donald Perkins - Particle Astrophysics (Oxford Master Series in Particle Physics, Astrophysics, and Cosmology), Oxford Univ. Press 2005
I. Lazanu – Cosmologie si particule elementare, Ed. Univ. din Bucuresti 1999

7.2 Tutorials	**Teaching techniques**	**Observations**
Problems in elementary particle physics Numerical application sin cosmology; discussions	Guided work. Exercises	6 Hours
Experimental determination of some properties of elementary particles (electrical charge, mass, impulse, energy, life time), identification, fundamental interactions	Guided work. Exercises	4 Hours
Analysis and interpretation of data with the technique of Dalitz diagrams and establishment of quantum numbers based on theoretical considerations.	Guided work. Exercises	2 Hours
Interference of resonances. Theoretical and numerical study	Guided work. Exercises	4 Hours

Investigation of Hubble's law using real galaxy measurements with 2-4 m telescopes and emission / absorption spectra for several elements and estimating the age of the Universe.	Guided work. Exercises	6 Hours
Numerical programming of the neutrino oscillation phenomenon for different distance bases	Guided work. Exercises	4 Hours
Determination of the mass of neutrinos from the experimental data obtained from the supernova 1987A	Guided work. Exercises	2 Hours

References:

I. Lazanu, Particule elementare, astroparticule si elemente ale universului timpuriu (aplicatii numerice si probleme rezolvate), Ed. Univ. din Bucuresti 2002

Ray Hagedorn - Relativistic Kynematics, Academic Press, 1968

B.R.Martin - Statistics for Physicists, Plenum Press, 1971

Claus Grupen, Astroparticle Physics, Springer 2005

Ian R. Kenyon - General relativity, Oxford Univ. Press 1990

Donald Perkins - Particle Astrophysics (Oxford Master Series in Particle Physics, Astrophysics, and Cosmology), Oxford Univ. Press 2005

I. Lazanu - Cosmologie si particule elementare, Ed. Univ. din Bucuresti 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

In order to sketch the contents, to choose the teaching / learning methods, given the special importance of the discipline for applications in modern physics and technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (Heidelberg, University of Cambridge, University of Cambridge Gent, Laussane). The content of the discipline is according to the requirements of employment in research institutes in nuclear physics and engineering, medical laboratories that use nuclear methods in investigation and treatment (according to the law).

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/analyse specific examples	Writen examination	70%
Tutorial	- ability to use specific problem solving methods - ability to analyse the results	Homeworks/writen tests	30%
Minimal requirements for passing the exam	Correct understanding of the concepts and phenomena, the ability to work with them and obtain accurate numerical results on topics imposed. Requirements for mark 5 (10 points scale) - Carrying out all the activities during the semester - Obtaining note 5 by summing the points obtained at the activities during the course and examination, according to the weights specified		

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

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

Syllabus

Academic year 2025/2026
DI.206 Research activity practice

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Research activity practice						
2.2. Teacher	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu						
2.3. Tutorials/Practicals instructor(s)	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	project assessment	2.7.Classification	DA

3. Total estimated time

3.1. Hours per week	6	3.2. Lectures	0	3.3. Tutorials/Practicals/Projects	0/6/0
3.4. Total hours per semester	60	3.5. Lectures	0	3.6. Tutorials/Practicals/Projects	0/60/0
Distribution of estimated time for study					
Learning by using one’s own course notes, manuals, lecture notes, bibliography					158
Research in library, study of electronic resources, field research					79
Preparation for practicals/tutorials/projects/reports/homework					78
Tutorat					0
Other activities					0
3.7. Total hours of individual study					315
3.8. Total hours per semester					375
3.9. ECTS					15

4. Prerequisites (if necessary)

4.1. curriculum	Completion of courses from the first and second year curriculum
4.2. competences	Knowledge of mathematics, physics, programming languages and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology. R10. The student/graduate should know the norms and ethical principles regarding scientific research in the field, as well as develop a culture of responsibility in intellectual work. R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field. R10. The student/graduate should assimilate explicit norms (normative texts) or implicit ones (customs, practices) that regulate academic and research conduct in the field. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

Responsibility and autonomy	R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community. R10. The student/graduate should demonstrate solidarity, responsiveness, and support for strengthening academic integrity. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

7. Contents

7.3 Practicals	Teaching techniques	Observations
In accordance with the research topic chosen for the practice. The topics will lead to the definition of dissertation topics in accordance with the existing proposals.		4 Hours
Research topics (theoretical and experimental approaches specific to the fields of atomic and nuclear physics): (Coordinator: Prof.univ.dr. Mihaela SIN, Dr. Dan Mihai Filipescu) 1) Calculation of cross sections for neutron-induced reactions on plutonium isotopes (238Pu-242Pu) in the energy range 10 keV – 30 MeV 2) Calculation of the photo-fission cross sections for 230Th, 232Th in the energy range 3 - 30 MeV 3) Comparative analysis of the photo absorption sections calculated with the gamma force functions included in RIPL (Reference Library of input parameters) in the case of actinides 4) Modeling of the emission of prompt neutrons and prompt gamma quanta in nuclear fission 5) Investigating mass, charge, and kinetic energy distributions for fission fragments and initial nucle-ar fission products 6) The study of the periodicity of the nuclear prop-erties of radionuclide 7) Even-odd effects in nuclear fission These re-search topics require high-performance computing equipment (computer network and possibilities to store and access nuclear databases). They can be provided by the computing laboratories of the department.		8 Hours
(Coordinator: Conf.univ.dr. Vasile BERCU) 8) The study of free radicals generated by ionizing radiation 9) Studies in archaeophysics 10) Studies of paramagnetic ions in different systems of opto-electronic interest		8 Hours

(Coordinator: Conf.univ.dr. Oana RISTEA) 11) Study of radiation interaction with matter using GEANT4 12) Analysis of the constructive parameters of segmented electromagnetic calorimeters using GEANT4 13) Study of Coulomb interaction in relativistic nuclear collisions 14) Determination of thermal freezing parameters from the analysis of transverse momentum spectra using the ”blast-wave” model 15) Analysis of chemical freezing parameters using THERMUS model 16) Investigating the properties of hot, dense nuclear matter in relativistic nuclear collisions in the BRAHMS and CBM experiments 17) Conditions for formation and experimental signals of phases and phase transitions in hot dense nuclear matter 18) Experimental methods in nuclear physics, elementary particle physics and astroparticle physics		8 Hours
(Coordinator: Lect.univ.dr. Marius CĂLIN) 19) Obtaining dosimetric maps of the areas in Bucharest located in the vicinity of the CETs 20) The influence of the radiation dose absorbed by some seeds on their further evolution 21) Analysis by high-resolution gamma spectroscopy of some environmental samples (soil, vegetation, surface water) 22) Determination of the radon concentration in the buildings and its dependence on the age, the degree of damage, the structure of the walls (brick, concrete, wood), position on the city map, the degree of ventilation of the rooms 23) Application of simulation codes (FLUKA) to obtain a map of doses possibly present around given radioactive sources (emitting only one type of radiation or several types) 24) Using simulation codes for various experiments in Nuclear Physics, Particle Physics and Astroparticle Physics 25) Nuclear archaeology		8 Hours
(Coordinator: Lect. Dr. Mihaela PÂRVU, Prof. Dr. Ionel LAZANU) 26) Radioactive background studies in underground experiments for rare processes 27) Studies related to transient processes at the interactions of incident particles (neutrinos, muons, mesons) in materials used as detectors in particle and astroparticle physics (gaseous, liquid and solid argon, xenon, semiconductors) 28) Mechanisms of production of the isotope Ar-39 in Ar-40 29) Physics of solar neutrinos and neutrinos from supernovae 30) Physical processes and reaction channels for leptons above/beyond the Standard Model 31) Using passive detectors in radioactive background determinations		8 Hours

(Coordinator: Lect.univ.dr. Alecsandru Vladimir CHIROȘCA) 32) Dosimetry and radiation detection; modeling of detection parameters for all types of radiation 33) Neutron dosimetry and applications 34) Radiation transport modeling using the GEANT and Fluka codes 35) Dosimetry in radiation therapy at linear accelerators (GEANT, Gamos) 36) Statistical data processing (Python, ROOT) 37) Microcontrollers and IoT 38) The use of artificial intelligence systems in data processing 39) Modeling of radiation field production processes in high power lasers (1PW). Numerical modeling and PIC (Particle In Cell)		8 Hours
(Coordinator: Lect. dr. Radu Alin VASILACHE) 40) Measuring doses in Ultra High Dose Rate (UHDR) beams. Recombination measurements in ion chambers and models for the recombination at UHDR 41) Space dosimetry. Detectors for dose measurements in complex radiation fields similar to the interplanetary galactiv cosmic radiation 42) Internal dosimetry using whole body counters. Design of novel whole body counters 43) OSL dosimetry for personnel and area measurements. The design of the algorithms for complex field dosimetry using BeOSL dosimeters 44) High and medium resolution systems for the assay and sorting of radioactive waste. The design of automated systems for radioactive waste measurements 45) High resolution gamma spectroscopy for TL and OSL dating. The determination of annual doses in various soil samples.		8 Hours
References: It is established by the internship coordinator, in accordance with the field of activity and the chosen topics.		

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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in modern technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (University of Oxford https://www.ox.ac.uk/admissions/undergraduate/courses-listing?wssl=1, University of Parma http://www.difest.unipr.it/it/didattica/laurea-triennale-fisica/calendario-didattico, University of Padua, http://en.didattica.unipd.it/didattica/2015/SC1158/2014). The content of the discipline is according to the requirements for employment in research institutes in physics and materials science and in education (under the law).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Practical	- Attendance - The application of specific methods of solving the given problem; - Interpretation of results; - The clarity, coherence and brevity of the exposition - The correct use of models, formulas and relations of calculation;	Verification/ Colloquium	100%

Minimal requirements for passing the exam	Minimal requirements for passing the exam Requirements for mark 5 (10 points scale) • Mandatory attendance at all research activities Requirements for mark 10 (10 points scale) Experimental skills, well-argued knowledge and corect use of specific experimental techniques • Demonstrated ability to analyze phenomena and processes • Personal approach and interpretation

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu

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

Syllabus

Academic year 2025/2026

DI.207 Research activity and Dissertation thesis preparation

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Research activity and Dissertation thesis preparation
2.2. Teacher	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu
2.3. Tutorials/Practicals instructor(s)	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu

2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	project assessment	2.7.Classification	DA

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	Completion of courses from the first and second year curriculum
4.2. competences	Knowledge of mathematics, physics, programming languages and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology. R10. The student/graduate should know the norms and ethical principles regarding scientific research in the field, as well as develop a culture of responsibility in intellectual work. R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field. R10. The student/graduate should assimilate explicit norms (normative texts) or implicit ones (customs, practices) that regulate academic and research conduct in the field. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

Responsibility and autonomy	R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community. R10. The student/graduate should demonstrate solidarity, responsiveness, and support for strengthening academic integrity. R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

7. Contents

7.3 Practicals	**Teaching techniques**	**Observations**
In accordance with the research topic chosen for the dissertation.		1 Hour
Research topics (Coordinator: Prof.univ.dr. Mihaela SIN, Dr. Dan Mihai Filipescu) 1) Calculation of cross sections for neutron-induced reactions on plutonium isotopes (238Pu-242Pu) in the energy range 10 keV – 30 MeV 2) Calculation of the photo-fission cross sections for 230Th, 232Th in the energy range 3 - 30 MeV 3) Comparative analysis of the photo absorption sections calculated with the gamma force functions included in RIPL (Reference Library of input parameters) in the case of actinides 4) Modeling of the emission of prompt neutrons and prompt gamma quanta in nuclear fission 5) Investigating mass, charge, and kinetic energy distributions for fission fragments and initial nucle-ar fission products 6) The study of the periodicity of the nuclear prop-erties of radionuclide 7) Even-odd effects in nuclear fission These re-search topics require high-performance computing equipment (computer network and possibilities to store and access nuclear databases). They can be provided by the computing laboratories of the department.		6 Hours
(Coordinator: Conf.univ.dr. Vasile BERCU) 8) The study of free radicals generated by ionizing radiation 9) Studies in archaeophysics 10) Studies of paramagnetic ions in different systems of opto-electronic interest		5 Hours

(Coordinator: Conf.univ.dr. Oana RISTEA) 11) Study of radiation interaction with matter using GEANT4 12) Analysis of the constructive parameters of segmented electromagnetic calorimeters using GEANT4 13) Study of Coulomb interaction in relativistic nuclear collisions 14) Determination of thermal freezing parameters from the analysis of transverse momentum spectra using the ”blast-wave” model 15) Analysis of chemical freezing parameters using THERMUS model 16) Investigating the properties of hot, dense nuclear matter in relativistic nuclear collisions in the BRAHMS and CBM experiments 17) Conditions for formation and experimental signals of phases and phase transitions in hot dense nuclear matter 18) Experimental methods in nuclear physics, elementary particle physics and astroparticle physics		5 Hours
(Coordinator: Lect.univ.dr. Marius CĂLIN) 19) Obtaining dosimetric maps of the areas in Bucharest located in the vicinity of the CETs 20) The influence of the radiation dose absorbed by some seeds on their further evolution 21) Analysis by high-resolution gamma spectroscopy of some environmental samples (soil, vegetation, surface water) 22) Determination of the radon concentration in the buildings and its dependence on the age, the degree of damage, the structure of the walls (brick, concrete, wood), position on the city map, the degree of ventilation of the rooms 23) Application of simulation codes (FLUKA) to obtain a map of doses possibly present around given radioactive sources (emitting only one type of radiation or several types) 24) Using simulation codes for various experiments in Nuclear Physics, Particle Physics and Astroparticle Physics 25) Nuclear archaeology		6 Hours
(Coordinator: Lect. Dr. Mihaela PÂRVU, Prof. Dr. Ionel LAZANU) 26) Radioactive background studies in underground experiments for rare processes 27) Studies related to transient processes at the interactions of incident particles (neutrinos, muons, mesons) in materials used as detectors in particle and astroparticle physics (gaseous, liquid and solid argon, xenon, semiconductors) 28) Mechanisms of production of the isotope Ar-39 in Ar-40 29) Physics of solar neutrinos and neutrinos from supernovae 30) Physical processes and reaction channels for leptons above/beyond the Standard Model 31) Using passive detectors in radioactive background determinations		6 Hours

(Coordinator: Lect.univ.dr. Alecsandru Vladimir CHIROȘCA) 32) Dosimetry and radiation detection; modeling of detection parameters for all types of radiation 33) Neutron dosimetry and applications 34) Radiation transport modeling using the GEANT and Fluka codes 35) Dosimetry in radiation therapy at linear accelerators (GEANT, Gamos) 36) Statistical data processing (Python, ROOT) 37) Microcontrollers and IoT 38) The use of artificial intelligence systems in data processing 39) Modeling of radiation field production processes in high power lasers (1PW). Numerical modeling and PIC (Particle In Cell)		5 Hours
(Coordinator: Lect. dr. Radu Alin VASILACHE) 40) Measuring doses in Ultra High Dose Rate (UHDR) beams. Recombination measurements in ion chambers and models for the recombination at UHDR 41) Space dosimetry. Detectors for dose measurements in complex radiation fields similar to the interplanetary galactiv cosmic radiation 42) Internal dosimetry using whole body counters. Design of novel whole body counters 43) OSL dosimetry for personnel and area measurements. The design of the algorithms for complex field dosimetry using BeOSL dosimeters 44) High and medium resolution systems for the assay and sorting of radioactive waste. The design of automated systems for radioactive waste measurements 45) High resolution gamma spectroscopy for TL and OSL dating. The determination of annual doses in various soil samples.		6 Hours
References: It is established by the internship coordinator, in accordance with the field of activity and the chosen topics.		

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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in modern technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (University of Oxford https://www.ox.ac.uk/admissions/undergraduate/courses-listing?wssl=1, University of Parma http://www.difest.unipr.it/it/didattica/laurea-triennale-fisica/calendario-didattico, University of Padua, http://en.didattica.unipd.it/didattica/2015/SC1158/2014). The content of the discipline is according to the requirements for employment in research institutes in physics and materials science and in education (under the law).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Practical	- Attendance - The application of specific methods of solving the given problem; - Interpretation of results; - The clarity, coherence and brevity of the exposition - The correct use of models, formulas and relations of calculation;	Verification/ Colloquium	100%

Minimal requirements for passing the exam	Minimal requirements for passing the exam Requirements for mark 5 (10 points scale) • Mandatory attendance at all research activities • Preparation of the dissertation thesis Requirements for mark 10 (10 points scale) Experimental skills, well-argued knowledge and corect use of specific experimental techniques • Demonstrated ability to analyze phenomena and processes • Personal approach and interpretation

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu	Conf. dr. Oana Ristea, Lect. dr. Mihaela Parvu

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

Syllabus

Academic year 2025/2026
DO.106.1 Radionuclides, environmental radioactivity, and nuclear waste management

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Radionuclides, environmental radioactivity, and nuclear waste management						
2.2. Teacher	Conf. dr. Oana Ristea, Lect. dr. Radu Vasilache						
2.3. Tutorials/Practicals instructor(s)	Conf. dr. Oana Ristea, Lect. dr. Radu Vasilache						
2.4 Year of study	1	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DS

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					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	Nuclear Physics, Mathematics, Equations of mathematical physics, Quantum physics, Statistical physics. Numerical methods. Programming languages.
4.2. competences	Programming languages for science. Software for processing of nuclear data and graphics.

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom equipped with multimedia devices
5.2. for tutorials/practicals	Set of practical work illustrating the topics covered in the course.

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R4. The student/graduate knows the fundamental concepts of dosimetry as well as the principles and rules of radiological protection. R5. The student/graduate has advanced knowledge of the behavior of radionuclides in the environment, as well as of the natural and anthropogenic processes that influence environmental radioactivity. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R4. The student/graduate applies and evaluates safety and radiological protection regulations, applicable in educational and research laboratories. R5. The student/graduate uses sampling, analysis, and data interpretation methods for radioactive contamination, including spectrometry and dosimetry techniques applied in environmental contexts. R7. The student/graduate uses computing codes or software packages for research topics and specific applications.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R4. The student/graduate takes responsibility for complying with radiological protection norms and ethical standards in multidisciplinary teams. R5. The student/graduate complies with safety and radiation protection regulations, taking responsibility for risk assessment and the protection of the environment and public health. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Cosmic rays. Primary and secondary cosmic rays. Cosmogenic radionuclides. Production mechanisms and rates, example (C-14, H-3, Be-7 and other radionuclides). Applications	Systematic exposure - lecture. Examples.	4 Hours
Cosmogenic nuclides in situ, examples. Production mechanisms and rates (with or without erosion). Applications	Systematic exposure - lecture. Examples.	2 Hours
Natural decay series. Secular equilibrium, Applications.	Systematic exposure - lecture. Examples.	2 Hours
Natural radioactivity. Uranium. Thorium. Ra-266, Radon, Toron and their descendants. Distribution of radon and its descendants in the atmosphere. High natural background radiation areas. Contributions to the natural radioactive background	Systematic exposure - lecture. Examples.	3 Hours
Dating methods using radioactive isotopes (K-Ar, Rb-Sr, U-Pb methods, Pb-210 activity measurements in sediments). Applications	Systematic exposure - lecture. Examples.	3 Hours
Sources of exposure to ionising radiation. Radiotoxicity. Biokinetic models for the assay of internal doses due to the incorporation of radionuclides. Dose - response models used to evaluate the risk of exposure to ionising radiation. Applications	Systematic exposure - lecture. Examples.	2 Hours
The assessment of exposure to indoor radon. Potential alfa energy (PAE) and PAE concentration (PAEC). Radon / thoron equilibrium indoors; the equilibrium coefficient. Building materials as sources of radon. Radon attachment to the aerosols. Indoor radon measurements. Doses due to radon and descendants. Standards and regulations related to radon exposure. Applications	Systematic exposure - lecture. Examples.	2 Hours

Radioactive contamination of the environment. Sources of contamination. NORM and TENORM. Radioactive effluents. Methods for establishing the derived limits for radioactive effluents. Applications	Systematic exposure - lecture. Examples.	2 Hours
Nuclear and radiological accidents and incidents. The INIS scale. Models for the atmospheric dispersion of radioactive emissions. Environmental contamination subsequent to the accidents and methods for environmental monitoring. Rules for the response to nuclear / radiological accidents. Examples: the Chernobil and Fukushima accidents. The radiological accident from Gôiania. applications	Systematic exposure - lecture. Examples.	4 Hours
Managament of radioactive waste. Categorising and characterisation of radioactive waste. Processing and storage of radioactive waste. Orphan sources. Examples.	Systematic exposure - lecture. Examples.	4 Hours

References:

1. G.Vladuca ”Elemente de fizica nucleara”, partea I, Ed.Univ.Buc., 1988.
2. G.Vladuca ”Elemente de fizica nucleara”, partea a II-a, Ed.Univ.Buc., 1990.
3. O. Sima, Note de curs Radioactivitatea mediului.
4. A.Tudora, E.Sartori ”Biblioteci de date nucleare si coduri de calcul din domeniul nuclear ≫, Ed.Univ. Buc.1999.
5. V. Valcovic, Radioactivity in the environment, Elsevier, 2000.
6. M. Eisenbud, T. Gessel, Environmental radioactivity, Academic Press, 1997
7. M. L'Anunziata, Handbook of Radioactivty Analysis, Academic Press 2012
8. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), editiile din 1988, 1993, 1996, 2000, 2008, 2010 etc.; http://www.unscear.org/unscear/en/publications.html
9. V.Cuculeanu ”Fizica si calculul reactorilor nucleari cu neutroni rapizi”, Ed.Teh.,Buc., 1982
10. Reveica Ion-Mihai, Radioactivitatea si circuitul izotopilor radioactivi in mediu, Ed. Univ.Buc., 1998.
11. O.Duliu, Aplicatiile radioatiilor nucleare, Ed.Univ.Buc., 1993.
12. C. Cosma, T. Jurcut, Radonul si mediul inconjurator, Editura Dacia, 1996

7.3 Practicals	**Teaching techniques**	**Observations**
Applications concerning the radioactive series and the secular equilibrium.		4 Hours
Gamma spectrometry with NaI(Tl) detectors. Gamma spectrometry analysis of a pitchblende sample		2 Hours
Study of self-absorption effects in thick radioactive samples		2 Hours
Determination of the density variation of samples by the transmission of beta radiation		2 Hours
Measurement of the half-life of 40K using a KCl sample		2 Hours
Data analysis to obtain isochronous curves in dating applications		2 Hours
The calculation of derived activity concentrations for water and air effluents.		2 Hours
Evaluation of radioactive contamination of the environment after a single emission incident using the Gaussian dispersion model.		4 Hours
Methods for finding and identifying an orphan source		2 Hours
Practical exercise of intervention in the case of a nuclear accident		4 Hours
Measurement of area contamination using low level alpha beta counting.		2 Hours

References:

1. G.Vladuca ”Elemente de fizica nucleara”, partea I, Ed.Univ.Buc., 1988.
2. G.Vladuca ”Elemente de fizica nucleara”, partea a II-a, Ed.Univ.Buc., 1990.
3. A.Tudora, E.Sartori ”Biblioteci de date nucleare si coduri de calcul din domeniul nuclear≫, Ed.Univ. Buc.1999.
4. O. Sima, Note de curs Radioactivitatea mediului.
5. Reveica Ion-Mihai, Radioactivitatea si circuitul izotopilor radioactivi in mediu, Ed. Univ.Buc., 1998.
6. O.Duliu, Aplicatiile radioatiilor nucleare, Ed.Univ.Buc., 1993.

IAEA (www.iaea.org), IAEA Nuclear Data Section (www-nds.iaea.org): the nuclear data libraries RIPL and EXFOR.

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

Given the special importance of the discipline for applications in the field of nuclear physics (multiple applications in all fields, industry, medicine, agriculture, energy, etc.) in order to prepare the contents and choose the teaching/learning methods, the teachers of the discipline consulted the content of similar couses taught at universities abroad (Université de Bordeuaux, Université Paris-Sud, Université Catholique Louvain-la-Neuve, etc.). The content of the discipline is in accordance with the employment requirements in research institutes in the field of nuclear physics and nuclear reactors, at nuclear power plants and in higher education field (according to the law).

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 analyze specific examples	Oral examination	70%
Practical	- ability to use specific methods to solve a given problem. - ability to analyze the lab data - interpretation of the results	Lab reports	30%
Minimal requirements for passing the exam	Minimal requirements for passing the exam Correct understanding of the concepts and phenomena, the ability to work in a team and to obtain accurate numerical results on topics imposed. Requirements for mark 5 (10 points scale) • Finalization of the tasks given during the practical activities. • Correct exposure of the subjects indicated to obtain 5 at the final exam.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. dr. Oana Ristea, Lect. dr. Radu Vasilache	Conf. dr. Oana Ristea, Lect. dr. Radu Vasilache

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

Syllabus

Academic year 2025/2026
DO.106.2 Applications of Nuclear Physics in life sciences and medicine

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Applications of Nuclear Physics in life sciences and medicine
2.2. Teacher	Lect. dr. Marius Calin
2.3. Tutorials/Practicals instructor(s)	Lect. dr. Marius Calin

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

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	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	Atomic physics, Nuclear physics, Optics, Quantum physics, Statistical physics
4.2. competences	Fission and fusion processes, nuclear reactors, nuclear spectroscopy, nuclear reactions mechanims

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom (with multimedia facilities)
5.2. for tutorials/practicals	Experimental setups from Nuclear Physics Laboratory, Computer Network (or individual laptops)

6. Learning outcomes

Knowledge	R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R4. The student/graduate knows the fundamental concepts of dosimetry as well as the principles and rules of radiological protection. R5. The student/graduate has advanced knowledge of the behavior of radionuclides in the environment, as well as of the natural and anthropogenic processes that influence environmental radioactivity. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.

Skills	R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R4. The student/graduate applies and evaluates safety and radiological protection regulations, applicable in educational and research laboratories. R5. The student/graduate uses sampling, analysis, and data interpretation methods for radioactive contamination, including spectrometry and dosimetry techniques applied in environmental contexts. R7. The student/graduate uses computing codes or software packages for research topics and specific applications.
Responsibility and autonomy	R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R4. The student/graduate takes responsibility for complying with radiological protection norms and ethical standards in multidisciplinary teams. R5. The student/graduate complies with safety and radiation protection regulations, taking responsibility for risk assessment and the protection of the environment and public health. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Autoradiographic method Autoradiography and microauthoradiography Radionuclides used in autoradiography: C-14, P-32, S-35 and I-125. Radiographic film – detector for nuclear radiation Gas-discharge detectors used in digital autoradiography Radiopharmaceuticals and tracers used in autoradiography. Performance and limitations. Examples of the use of autoradiography and microradioagraphy	Systematic exposition - lecture. Examples	8 Hours
Emissional nuclear imaging Gamma Chamber Radionuclides 99mTc, 123I, 201Tl and associated radiopharmaceuticals Construction, acquisition of scitigraphic images. Performance and limitations Uniphotonic emissive tomography (SPEC) – 3D extension of the gamma chamber. Performance and limitations Beta-plus radionuclides compatible with tissues: 11C, 13N, 15O, 18F, 82Ru and associated radiopharmaceuticals Positron emission tomography (PET). Performance and limitations Examples of the use of gamma chamber, SPECT and PET in medicine and biology:body scann, liver and thyroid scintigraphy, etc.	Systematic exposition - lecture. Examples	8 Hours

Nuclear analytical techniques in medicine Radioimmunology. Performance and limitations. Examples	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	6 Hours
Special problems of dosimetry and radioprotection in nuclear medicine Internal irradiation and calculation of effective equivalent doses for gamma and beta emitters. In-situ measurement of absorbed doses (TLD and ionization micro-chambers).	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours
Quality assurance in nuclear medicine Criteria for quality assurance in the case of exploratory and curative medicine	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours
Methods of radioimmunoanalysis and other methods of investigation of the living substance	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours

References:

Rogers, A. W (1979). Techniques of Autoradiography (3rd ed.). New York: Elsevier North Holland. ISBN 0-444-80063-8.
(1982) Quality Assurance in Nuclear Medicine, World Health Organization, ISBN: 92-4-154165-2
Hatzialekou, U., Henshaw, D.L., Fews, A.P. (1982) Automated image analysis of alpha-particle autoradiographs of human bone, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 263, 504-514
Chard, T. (1995) An Introduction to Radioimmunoassay and Related Techniques, Fifth Edition, Elsevier Science, ISBN: 978-0444821195
Petegnief Y, Aubineau-Laniece I, Kerrou K, Jourdain JR, Talbot JN. (2001) Advanced radionuclide detection techniques for in vitro and in vivo animal imaging. Cell and Molecular Biology (Noisy-le-Grand). 47, 443-51.
Khan, T. S., Sundin, A., Juhlin, C., Långström, B., Bergström, M., Eriksson, B. (2003). "11C-metomidate PET imaging of adrenocortical cancer". European Journal of Nuclear Medicine and Molecular Imaging 30 (3): 403–410. doi:10.1007/s00259-002-1025-9
Bailey, D.L, Townsend, D.W., Valk, P.E., Maisey, M.N. (2005). Positron Emission Tomography: Basic Sciences. Springer-Verlag. Heidelberg, ISBN 1-85233-798-2.
Brix, G., Lechel, U., Glatting, G., et al. (2005). "Radiation exposure of patients undergoing whole-body dual-modality 18F-FDG PET/CT examinations". Journal of Nuclear Medicine 46, 608–613
Phelps, M.E. (2006). PET: physics, instrumentation, and scanners. Springer-Verlag, Heidelberg. ISBN 0-387-34946-4
Bushberg, J.T., Seibert, J.A., Leidholdt Jr., E.M., Boone, J.M. (2012) The Essential Physics of Medical Imaging, Third Edition, Lippincotl Williams and Wilkins, Philadelphia, ISBN-13: 978-0781780575
Hörtnagl, H., Tasan, R.O., Wieselthaler, A., Kirchmair, E., Sieghart, W., Sperk, G. (2013) Patterns of mRNA and protein expression for 12 GABAA receptor subunits in the mouse brain, Neuroscience, (In Press) disponibil on-line pe ScienceDirect.

7.3 Practicals	**Teaching techniques**	**Observations**
Measurement of environmental samples. Specific applications	Guided practical activity	2 Hours
Specific calculation codes used to measure the radioactivity of samples of low activity. Applications	Guided practical activity	6 Hours
Specific calculations for measuring the activity of descendants of radon and thoron. Applications	Guided practical activity	6 Hours
Calculation codes for estimating the doses and the associated risks	Guided practical activity	6 Hours
Detectors for measuring the radioactivity of environmental samples. Radon detectors. Problems	Guided practical activity	4 Hours
Problems		4 Hours

References:
G.Vladuca « Elemente de fizica nucleara, partea I », Ed.Univ.Buc., 1988.
G.Vladuca « Elemente de fizica nucleara, partea a II-a », Ed.Univ.Buc., 1990.
A.Tudora, E.Sartori "Biblioteci de date nucleare si coduri de calcul din domeniul nuclear », Ed.Univ. Buc.1999.
O. Sima, Note de curs Radioactivitatea mediului.
Reveica Ion-Mihai, Radioactivitatea si circuitul izotopilor radioactivi in mediu, Ed. Univ.Buc., 1998.
O.Duliu, Aplicatiile radioatiilor nucleare, Ed.Univ.Buc., 1993.

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

In order to sketch the contents, to choose the teaching / learning methods, given the special importance of the discipline for applications in modern physics and technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (Université de Bordeuaux, Université Paris-Sud, Université Catholique Louvain-la-Neuve etc). The content of the discipline is according to the requirements of employment in research institutes in nuclear physics and engineering, medical laboratories that use nuclear methods in investigation and treatment (according to the law).

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/analyse specific examples	Written examination	50%
Practical	- ability to use specific problem solving methods - ability to analyse and discuss the results	Homeworks/writen tests	50%
Minimal requirements for passing the exam	Minimal requirements for passing the exam Correct understanding of the concepts and phenomena, the ability to work with them and obtain accurate numerical results on topics imposed. Requirements for mark 5 (10 points scale) At least 50% of exam score and correct solving of a problem. Requirements for mark 10 (10 points scale) Correct solving of all exam topics.		

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

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

Syllabus

Academic year 2025/2026
DO.110.1 Models for nuclear structure, nuclear and photonuclear reactions

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title		Models for nuclear structure, nuclear and photonuclear reactions					
2.2. Teacher		Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea					
2.3. Tutorials/Practicals instructor(s)		Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea					
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DA

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					72
Research in library, study of electronic resources, field research					36
Preparation for practicals/tutorials/projects/reports/homework					36
Tutorat					0
Other activities					0
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	Nuclear Physics, Interaction of ionizing radiations with matter, Mathematics, Quantum Physics, Statistical Physics
4.2. competences	Nuclear Physics, Interaction of ionizing radiations with matter, Mathematics, Quantum Physics, Statistical Physics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia room equipped with internet connection and video-projector.
5.2. for tutorials/practicals	Multimedia room equipped with internet connection and video-projector, computers, specific codes.

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R9. The student/graduate has in-depth knowledge of the mechanisms of nuclear fission and fusion processes, nuclear structure models, and their applications in energy and technology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R9. The student/graduate is capable of analyzing and comparing different nuclear processes, using theoretical models and computational tools to evaluate nuclear reactions and energy production.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R9. The student/graduate can participate in projects concerning the sustainable development of nuclear energy sources, taking responsibility for evaluating the scientific, technological, and ethical impact of adopted decisions.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Review of the nuclear physics and quantum mechanics notions which enter the nuclear structure and interaction modeling.	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours
Nuclear forces. Nuclear potential.	Systematic exposition - lecture. Heuristic conversation.	2 Hours
Nuclear structure models. Hypothesis and experimental arguments. Independent- particle models Collective models. Unified model. Predicted quantities.	Systematic exposition - lecture. Heuristic conversation.	6 Hours
Theoretical elements of alpha, beta and gamma decay.	Systematic exposition - lecture. Heuristic conversation.	4 Hours
Nuclear reactions: classification, kinematics, observables. Reaction cross sections.	Systematic exposition - lecture. Heuristic conversation.	2 Hours
Reaction mechanisms: direct interaction, preequilibrium emission, compound nucleus formation and decay. Experimental arguments.	Systematic exposition - lecture. Examples	2 Hours
Nuclear reaction modeling. Scattering matrix. Analysis of resolved and unresolved resonances. Statistical models: optical model, Hauser-Feshbach model.	Systematic exposition - lecture.	4 Hours
Transmission coefficients for particles, gamma-decay and fission. Model parameters.	Systematic exposition - lecture. Examples	4 Hours
Photo-nuclear reactions. Photo-absorption, strength functions, giant dipole resonances.	Systematic exposition - lecture. Examples	2 Hours

References:
1. G.Vlăducă, Elemente de fizică nucleară I , Ed.Univ.Buc., 1989
2. G.Vlăducă, Elemente de fizică nucleară II, Ed.Univ.Buc., 1990
3. G.Vlăducă, Reacţii nucleare şi fisiune nucleară, Ed.Univ.Buc., 1981
4. M. Sin, Lecture Notes
5. David J. Rowe, John L. Wood, Fundamentals of Nuclear models, World Scientific, 2010
6. Hans Paetz gen. Schieck, Nuclear Reactions An Introduction, Springer, 2014

7.3 Practicals	**Teaching techniques**	**Observations**
Applications of the conservation laws as selection rules in nuclear physics.	Examples. Solving problems.	2 Hours
Comparison between the structure model predictions and the experimental data.	Examples. Solving problems. Employing data bases.	4 Hours
Comparison between the decay theory predictions and the experimental data.	Examples. Solving problems. Employing data bases.	4 Hours
Calculations of kinematic quantities for nuclear reactions.	Examples. Solving problems.	2 Hours
Reaction model input parameters retrieval from RIPL.	Examples. Employing data bases.	4 Hours
Nuclear reaction induced by neutrons and charged particles on medium nuclei calculations.	Examples. Employing data bases.	4 Hours
Nuclear reaction induced by neutrons and photons on fissionable nuclei calculations.	Examples. Employing data bases.	4 Hours
Sensitivity studies. Uncertainties and correlations estimation for the reaction quantities. Covariance matrix calculation.	Examples. Employing data bases.	4 Hours

References:
1. G.Vlăducă, Reactii nucleare – probleme, Ed.Univ.Buc., 1979
2. G.Vlăducă, Probleme avansate de fizică nucleară , Ed.Univ.Buc., 1997
3. www-nds.iaea.org: ENSDF, Live Chart of Nuclides, ENDF, EXFOR, RIPL, EMPIRE, Photonuclear

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 is important for the theoretical and experimental physics, as well as for all the fields which benefit from nuclear methods and techniques. Therefore the subjects are treated from theoretical, experimental, calculation/simulation and users' perspectives. This approach is the result of teaching and research expertise, of the analysis of similar courses and of the interaction with research institutes and international agencies which coordinates the nuclear activities world-wide. The content of the course is in line with the requirements/expectations of the potential employers of our master graduates.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- appropriate approach of the subject - coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyze specific examples	Oral examination	50%
Tutorial			50%
Minimal requirements for passing the exam	Correct treatment of specified subjects.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea

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

Syllabus

Academic year 2025/2026
DO.110.2 Experimental physics of heavy-ions at low energies

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Experimental physics of heavy-ions at low energies						
2.2. Teacher	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DA

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					72
Research in library, study of electronic resources, field research					36
Preparation for practicals/tutorials/projects/reports/homework					36
Tutorat					0
Other activities					0
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	Mathematical Analysis, Theoretical Mechanics, Optics, Atomic Physics, Nuclear Physics, Particle Physics, Electrodynamics, Statistical Physics, Experimental Methods in Nuclear Physics
4.2. competences	Programming Languages; Numerical Methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia room equipped with internet connection and video-projector.
5.2. for tutorials/practicals	Multimedia room equipped with internet connection and video-projector, computers, specific codes.

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R9. The student/graduate has in-depth knowledge of the mechanisms of nuclear fission and fusion processes, nuclear structure models, and their applications in energy and technology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R9. The student/graduate is capable of analyzing and comparing different nuclear processes, using theoretical models and computational tools to evaluate nuclear reactions and energy production.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R9. The student/graduate can participate in projects concerning the sustainable development of nuclear energy sources, taking responsibility for evaluating the scientific, technological, and ethical impact of adopted decisions.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
First experiments with heavy ions at low energies. Discovery of the fission isomers. Strutinski's theory. Nuclear structure models and perfecting the mass formula from the liquid drop model to explain the synthesis of elements in the Universe	Systematic exposition - lecture. Heuristic conversation. Examples	4 Hours
Kinematics of the nuclear reactions. Specific features of the heavy ion reactions. Deflection function in the electric field of punctiform electric charge, extended electric charge, respectively. Heavy ions trajectories. Classification of the reactions induced by heavy ions using different criteria. Applications of the heavy ion reactions (PIXE, PIGE, Rutherford back-scattering etc.).	Systematic exposition - lecture. Heuristic conversation. Examples	4 Hours
Heavy Ions Physics at the tandem accelerators. IFIN-HH case. Tandem description (heavy ion sources, tandem structure, nuclear targets). Experimental set-ups for heavy ion experiments.	Systematic exposition - lecture. Heuristic conversation. Examples	4 Hours
Reactions induced by radioactive beams. Exotic nuclei. Petraşcu's method for obtaining exotic nuclei. IFIN-HH and RIKEN experiments for obtainig exotic nuclei in heavy ions induced reactions at low energies.	Systematic exposition - lecture. Heuristic conversation. Examples	4 Hours
Nuclear potentials used in the study of the heavy ion reactions at low energies	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours
Heavy ions fusion. Theoretical aspects and experimental conditions. Specific reaction mechanisms in heavy ions fusion. Energy dependence of the fusion cross sections of the heavy ions. Experimental results	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours

Deep inelastic reactions with heavy ions. Conservative and dissipative forces. Double nuclear system formation. Lagrange formalism. Gross and Kalinovsky model.	Systematic exposition - lecture. Heuristic conversation.	4 Hours
Elastic scattering of the heavy ions. Classical model and deflection function. Diffractive models (Fresnel and Fraunhoffer). Optical model and complex nuclear potential.	Systematic exposition - lecture. Heuristic conversation. Examples	2 Hours
Search for super-heavy elements in heavy ion reactions. Perspectives in Heavy Ion Physics at Low Energy.	Systematic exposition - lecture. Heuristic conversation.	2 Hours

References:

1. A Das and T. Ferbel - Introduction to Nuclear and Particle Physics, World Scientific, Second edition, 2005
2. B.R.Martin – Statistics for Physicists, Plenum Press, 1971
3. Anişoara Constantinescu - Reactii nucleare cu ioni grei – Editura Universităţii din Bucureşti, 1993
4. K.Heyde – Basic Ideas and Concepts in Nuclear Physics – IOP Bristol and Philadelphia , 1999
5. K. Bethge (editor) - Experimental Methods in Heavy Ion Physics - Lectures Notes in Physics 83(1978)1-251
6. Valery Zagrebaev – Heavy Ion Reactions at Low Energies - Lectures Notes in Physics 963(2019)1-148
7. R. Prasad, B.P. Singh – Fundamentals and Applications of Heavy Ion Collisions (Below 10 MeV/Nucleon Energies) – Cambridge University Press, 2018 (318 pages)
8. Stefaan Tavernier - Experimental Techniques in Nuclear and Particle Physics – Springer - Springer Heidelberg Dordrecht London New York, 2010 (312 pages)
9. O.Bersillon - The Computer Code SCAT2, CEA-N-2227, 1981
10. Isao Tanihata et al - Phys.Lett.160B(1985)380
11. M.Petraşcu et al - Nucl.Phys. A790(2007)235c-240c
12. C. Beşliu, Al. Jipa – Modele de structură nucleară şi mecanisme de reacţie – Editura Universităţii din Buureşti, 2002

7.3 Practicals	Teaching techniques	Observations
Production methods of nuclear targets - in collaboration with NFD from IFIN-HH	Practical activity	4 Hours
Realization of the experimental set-up for the study of heavy ion reactions - in collaboration with NFD from IFIN-HH	Practical activity	4 Hours
Study of the heavy ion trajectories in electric fields	Practical activity	4 Hours
Study of the heavy ions trajectories in electric and nuclear fields for obtaining of the deflection functions	Practical activity	4 Hours
Utilization of the different calculus programs in the processing of the simulated data and experimental data from the study of heavy ion reactions at low energies (ROOT, different libraries etc.)	Practical activity	4 Hours
Study of the nuclear potential for different heavy ion reactions at low energies	Practical activity	2 Hours
Study of the heavy ion fusion reactions. Fits of the model predictions to the existing experimental results on heavy ion fusion	Practical activity	2 Hours
Study of the elastic scattering cross-sections in different heavy ion reactions at low energies	Practical activity	2 Hours
Problem solving		2 Hours

References:
1. A Das and T. Ferbel - Introduction to Nuclear and Particle Physics, World Scientific, Second edition, 2005
2. B.R.Martin – Statistics for Physicists, Plenum Press, 1971
3. Anişoara Constantinescu - Reactii nucleare cu ioni grei – Editura Universităţii din Bucureşti, 1993
4. K.Heyde – Basic Ideas and Concepts in Nuclear Physics – IOP Bristol and Philadelphia , 1999
5. K. Bethge (editor) - Experimental Methods in Heavy Ion Physics - Lectures Notes in Physics 83(1978)1-251
6. Valery Zagrebaev – Heavy Ion Reactions at Low Energies - Lectures Notes in Physics 963(2019)1-148
7. R. Prasad, B.P. Singh – Fundamentals and Applications of Heavy Ion Collisions (Below 10 MeV/Nucleon Energies) – Cambridge University Press, 2018 (318 pages)
8. Stefaan Tavernier - Experimental Techniques in Nuclear and Particle Physics – Springer - Springer Heidelberg Dordrecht London New York, 2010 (312 pages)
9. O.Bersillon - The Computer Code SCAT2, CEA-N-2227, 1981
10. Isao Tanihata et al - Phys.Lett.160B(1985)380
11. M.Petraşcu et al - Nucl.Phys. A790(2007)235c-240c
12. C. Beşliu, Al. Jipa – Modele de structură nucleară şi mecanisme de reacţie – Editura Universităţii din Buureşti, 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

This course forms/develops some theoretical competences and/or abilities that are important/fundamental for the student that graduate in the domain of the Modern Physics, in agreement with the national and European/international standards. The contents and the teaching methods have been selected after a careful and detailed analysis of the specific course units from the curricula of different important Universities from Europe and United (University of Oxford, University of Parma, University of Padova, University of California (see, for example
https://www.ox.ac.uk/admissions/undergraduate/courses-listing?wssl=1,
http://www.difest.unipr.it/it/didattica/laurea-triennale-fisica/calendario-didattico, http://en.didattica.unipd.it/didattica/2015/SC
The course structure and content are in agreement with the requirements and expectations of the possible employers (Higher Education, Research, Industry etc.)

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	The correct consideration on the subject extracted at examination. Clarity and coherence of presentation Right utilization of the models, formulas and relationships in calculation of the physical quantities Personal computing programs realized for a given subject	Oral examination	60%
Practical	- Ability for analyzing of the experimental or simulated data and the capacity to evaluate the obtained results and good description of the used methods at the practical classes evaluation - Periodic testing during the semester - Homeworks during the semester	Short reports on the individual work	40%
Minimal requirements for passing the exam	Correct treatment of specified subjects.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea

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

Syllabus

Academic year 2025/2026
DO.111.1 Detection methods in Physics of atom, nucleus, elementary particles, and Astrophysics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Detection methods in Physics of atom, nucleus, elementary particles, and Astrophysics						
2.2. Teacher	Mihaela Parvu, Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Mihaela Parvu, Oana Ristea						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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					72
Research in library, study of electronic resources, field research					36
Preparation for practicals/tutorials/projects/reports/homework					36
Tutorat					0
Other activities					0
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	
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 deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
General properties of detectors	Systematic exposition - lecture. Examples	4 Hours
The main physical phenomena used for the detection of particles and constructive classes of detectors: Ionization in gases: detectors without amplification, proportional counters, Geiger counters, detectors with streamer, in liquids and in solid environment; scintillation counters, photomultipliers and photodiodes, Cerenkov effect and detectors, transition radiation and detectors; other principles: fog chamber, bubble, streamer, spark, nuclear emulsion, halide crystals, thermoluminescence, plastics, fluorescence, radio detection, bolometric detectors at cryogenic temperatures (mKelvin)	Systematic exposition - lecture. Examples	10 Hours
Detector classes: a) Trace detectors: multi-wire proportional chambers, planar drift chambers, cylindrical wire chambers (proportional, temporary projection chambers), gaseous detectors, semiconductor track detectors, scintillation fibers. b) Calorimeters: electromagnetic, hadronic, cryogenic, other applications; c) Particle identification: charged particles (through flight time, through energy losses through ionization, Cerenkov, transition radiation);calorimeter identification, neutron detection, d) Neutrino detectors; e) Detection of muons; f) Detection of ultra high energy grasses; g) Cryogenic detectors for dark matter	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	14 Hours

References: 1) G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000 2) W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003). 3) C. Grupen, B. A. Swartz, Particle Detectors, Cambridge University Press 2008 4) Claus Grupen, Astroparticle Physics, Springer-Verlag Berlin Heidelberg 2005 4) Particle Data Group, http://pdg.lbl.gov 5) I. Lazanu, Mihaela Parvu, Detectori de particule - Îndrumar de laborator, aplicatii numerice şi probleme - forma electronic

7.3 Practicals	Teaching techniques	Observations
Investigation and analysis of signals in gas detection systems, scintillators and semiconductors and in associated electronics modules	Guided work	4 Hours
Experimental determination of the detection characteristics for different types of detectors	Guided work	12 Hours
Testing of a spectrometric chain scintillator type detector capable of discriminating the neutron gamma signal (fast and slow)	Guided work	4 Hours
Spatial and temporal correlations for gamma radiation investigated with scintillating detectors	Guided work	2 Hours
MC simulations for particle detectors		6 Hours

References: I. Lazanu, Mihaela Parvu, Detectori de particule - Îndrumar de laborator, aplicatii numerice şi probleme - format electronic

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	- coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyse specific examples	Oral examination	70%
Tutorial	- ability to use specific problem solving methods - ability to analyse the results	Homeworks/writen tests	10%
Practical	- ability to use specific experimental methods/apparatus - ability to perform/design specific experiments - ability to present and discuss the results	Lab reports	20%
Minimal requirements for passing the exam	- Carrying out all the activities during the semester - Obtaining note 5 by summing the points obtained at the activities during the course and examination, according to the weights specified		

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

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

Syllabus

Academic year 2025/2026
DO.111.2 Large experiments in Nuclear Physics, Particle Physics and Astrophysics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Large experiments in Nuclear Physics, Particle Physics and Astrophysics						
2.2. Teacher	Lect. Dr. Mihaela Pârvu, Conf. Dr. Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Mihaela Pârvu, Conf. Dr. Oana Ristea						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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	72
Research in library, study of electronic resources, field research	36
Preparation for practicals/tutorials/projects/reports/homework	36
Tutorat	0
Other activities	0
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	Equations of mathematical physics, Electricity, Atomic physics, Nuclear physics, Optics, Quantum physics, Statistical physics
4.2. competences	Physical data processing and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom (preferably, but not required, multimedia facilities)
5.2. for tutorials/practicals	Experimental set-ups from the Laboratory of Nuclear Physics, the Laboratory of Nuclear Spectroscopy and Detectors

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Underground astrophysics experiments The purpose of these experiments: a) Searching for dark matter and dark energy from the Universe: direct and indirect searches b) Double beta disintegrations without neutrinos, c) The physics of neutrinos: c1) Sources of neutrinos: supernovae, sun, atmospherics, geoneutrinos, accelerators, (beams, neutrino factories), reactors, relic neutrinos; c2) Oscillations of neutrinos. Experiments with different distance bases from tens of cm thousands of miles away; c3) Direct mass search d) Stability of matter - proton decay	Systematic exposition - lecture. Examples	14 Hours
Detection principles: ionization, Cerenkov radiation, scintillations, temperature (phonons), bubbles, microbubbles, tracking	Systematic exposition - lecture. Examples	4 Hours
Technologies: bolometric calorimetry, semiconductor and scintillation crystal calorimetry, liquid / gas calorimetry, temporary projection chamber, bubble chamber, other techniques	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	4 Hours
The main experiments The problem of the radioactive fund underground	Systematic exposition - lecture. Heuristic conversation. Critical analysis. Examples	6 Hours

References:
Bibliography: 1) G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000 2) W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003). 3) Claus Grupen, Astroparticle Physics, Springer-Verlag Berlin Heidelberg 2005 4) Particle Data Group, http://pdg.lbl.gov 5) http://www.aspera-eu.org/images/stories/Roadmap/brussels-petronzio.pdf 6) OECD Global Science Forum, Report of the Working Group on Astroparticle Physics, MARCH 2011 http://www.oecd.org/sti/scienceandtechnologypolicy/47598026.pdf 7) L. Pandola, Overview of the European Underground Facilities, arXiv:1102.020 8) I. Lazanu, Mihaela Parvu, Detectori de particule - Îndrumar de laborator, aplicatii numerice şi probleme – forma electronic

7.3 Practicals	Teaching techniques	Observations
a) Numerical applications and simulations: a1) Calculation of the rate of events in direct search of dark matter experiments; a2) Calculation of the oscillation probabilities for neutrino in different theoretical hypotheses	Guided work	4 Hours
b) Calculation of energy losses for high energy particles (electrons, positron and delta electrons) using information obtained in the bubble chamber and streamer - experimental determination of the Bethe-Bloch equation	Guided work	4 Hours
c) Simulations using FLUKA and or GEANT for particular processes specific to experiments in this class (will be specified at the beginning of the course)	Guided work	6 Hours
d) Atmospheric muon measurements in IFIN-HH and in the Slanic-Prahova underground laboratory.	Guided work	14 Hours

References:
I. Lazanu, Mihaela Parvu, Detectori de particule - Îndrumar de laborator, aplicatii numerice şi probleme – forma electronic

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

In order to sketch the contents, to choose the teaching / learning methods, given the special importance of the discipline for applications in modern physics and technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (Heidelberg, University of Cambridge, University of Cambridge Gent, Laussane). The content of the discipline is according to the requirements of employment in research institutes in nuclear physics and engineering, medical laboratories that use nuclear methods in investigation and treatment (according to the law).

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/analyze specific examples		60%
Practical	- ability to use specific experimental methods/apparatus - ability to perform/design specific experiments - ability to present and discuss the results	Lab reports	40%

Minimal requirements for passing the exam	Correct understanding of the concepts and phenomena, the ability to work with them and obtain accurate numerical results on topics imposed. Requirements for mark 5 (10 points scale) • Carrying out all the activities during the semester • Obtaining note 5 by summing the points obtained at the activities during the course and examination, according to the weights specified

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Mihaela Pârvu, Conf. Dr. Oana Ristea	Lect. Dr. Mihaela Pârvu, Conf. Dr. Oana Ristea

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

Syllabus

Academic year 2025/2026
DO.203.1 Nuclear fission and fusion. Nuclear reactors and nuclear energetics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Nuclear fission and fusion. Nuclear reactors and nuclear energetics
2.2. Teacher	Lect. Dr. Marius CĂLIN
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Marius CĂLIN

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

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	42	3.5. Lectures	14	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	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	Nuclear Physics, Nuclear reactions and structure. Equations of mathematical physics, Quantum physics, Statistical physics. Programming languages.
4.2. competences	Programming languages for science. Software for processing of nuclear data. Management of nuclear data library. Numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom (with multimedia facilities)
5.2. for tutorials/practicals	Computers connected in networks for accessing the nuclear data libraries of IAEA and of other major nuclear data centers.

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R5. The student/graduate has advanced knowledge of the behavior of radionuclides in the environment, as well as of the natural and anthropogenic processes that influence environmental radioactivity. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology. R9. The student/graduate has in-depth knowledge of the mechanisms of nuclear fission and fusion processes, nuclear structure models, and their applications in energy and technology.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R5. The student/graduate uses sampling, analysis, and data interpretation methods for radioactive contamination, including spectrometry and dosimetry techniques applied in environmental contexts. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field. R9. The student/graduate is capable of analyzing and comparing different nuclear processes, using theoretical models and computational tools to evaluate nuclear reactions and energy production.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R5. The student/graduate complies with safety and radiation protection regulations, taking responsibility for risk assessment and the protection of the environment and public health. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community. R9. The student/graduate can participate in projects concerning the sustainable development of nuclear energy sources, taking responsibility for evaluating the scientific, technological, and ethical impact of adopted decisions.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Basic features of the nuclear fission process (the post-scission part). Energetic in fission (energy release in fission, kinetic energy of fission fragments, excitation energy of fragments at full acceleration, etc.)	Systematic exposition - lecture. Examples	2 Hours
Mass and charge distributions of fission fragments, of initial and final fission products. Distributions of kinetic energy of fission fragments. Isobaric charge distributions of fission fragments.	Systematic exposition - lecture. Examples	2 Hours

Properties and behaviour of quantities, which characterize the fission fragments, the prompt neutron and prompt gamma-ray emission. Experimental set-ups and measurements of these quantities.	Systematic exposition - lecture. Examples	2 Hours
Partition of the total excitation energy between fully accelerated fission fragments based on modeling at scission.	Systematic exposition - lecture. Examples	2 Hours
Modeling of prompt emission in fission	Systematic exposition - lecture. Examples	2 Hours
Basic features of the pre-scission part of fission induced by neutrons. Statistical treatment of the fission channel in competition with other open channels. Level densities of the compound nucleus along the fission path. Fission cross-sections.Basic features of the nuclear fusion process. Principle of the Tokamak facility. ITER project.	Systematic exposition - lecture. Examples	2 Hours
Generations and types of nuclear reactors. Elements concerning the critically, the moderator, the fuel cycle and the cooler.	Systematic exposition - lecture. Examples	2 Hours

References:
1. G.Vladuca ≪ Elemente de fizica nucleara, partea a II-a ≫, Ed.Univ.Buc., 1990.
2. C.Wagemans (editor) ”The nuclear fission process” CRC Press, USA, 1991.
3. A.Berinde, G.Vladuca ≪ Reactii nucleare neutronice in reactor ≫ Ed.Teh.Buc., 1978.
4. A.Tudora, E.Sartori ”Biblioteci de date nucleare si coduri de calcul din domeniul nuclear ≫, Ed.Univ. Buc.1999.
5. G.Vladuca ≪ Reactii nucleare si fisiune nucleara ≫, Ed.Univ.Buc., 1981.
6. D.G.Madland, J.R.Nix, Nucl.Sci.Eng. (1982) 213-271
7. A.Tudora and F.-J.Hambsch, Eur.Phys.J.A 53 (2017) 159
8. OECD-Nuclear Energy Agency: The nuclear energy today / L'énergie nucléaire aujourd'hui, 2008.
9. R.Schulten, W.Guth ”Fizica reactorilor nucleari”, Ed.The.Buc.,1975.
10. V.Cuculeanu ”Fizica si calculul reactorilor nucleari cu neutroni rapizi”, Ed.Teh.,Buc., 1982
11. A.Berinde ”Elemente de Fizica si calculul reactorilor nucleari” Ed.Teh.Buc.1977
12. I.Purica, ”Teoria reactoarelor nucleare” Ed.Polith.Buc., 1982
13. B.Comby ”Energia nucleara si mediul”, Ed.TNR, 2001
14. R.Capote et al. ≪ Prompt fission neutron spectra of actinides ≫, Nucl.Data Sheets 131 (2016) 1-106

7.3 Practicals	**Teaching techniques**	**Observations**
Applications based on the distributions of fission fragments I. Calculation of single distributions Y(A), TKE(A), Y(TKE), Y(Z) etc. from a multiple fragment distribution Y(A,Z,TKE) given as input.	Guided work concerning the writing of computer codes providing the single distributions of fragments from an experimental multiple distribution Y(A,Z,TKE).	2 Hours
Applications based on the distributions of fission fragments II. Calculation of average values of different quantities characterizing the fission fragments.	Guided work concerning the writing of computer codes providing the average values of different quantities characterizing the fission fragments.	2 Hours
Applications based on the distributions of fission fragments II. Build of the fission fragment range using the isobaric charge distribution and the charge polarization. Highlight of the even-odd effects.	Exposure. Guided work for writing the related computer codes.	2 Hours

Prompt neutron multiplicity calculation using recent modelings I.	Exposure. Guided work for writing the first part of the related computer code, i.e. subroutines for the partition of total excitation energy between complementary fragments.	2 Hours
Prompt neutron multiplicity calculation using recent modelings II.	Exposure. Guided work for writing the second part of the related computer code, i.e. subroutines including the prompt emission.	2 Hours
Fit of experimental prompt neutron spectrum data with a Maxwellian spectrum.	Exposure. Guided work for writing the related computer code. Application for several sets of experimental data.	2 Hours
Modeling of prompt neutron spectrum using the most probable fragmentation approach, under the approximation of a constant compound nucleus cross-section of the inverse process of neutron evaporation from fragments.	Exposure. Guided work for writing the related computer code.	2 Hours
Applications based on fission fragment distributions I.	Guided practical activity	2 Hours
Applications based on fission fragment distributions II.	Guided practical activity	2 Hours
Applications based on fission fragment distributions III.	Guided practical activity	2 Hours
Prompt neutron multiplicity calculation based on new modelings I.	Guided practical activity	2 Hours
Prompt neutron multiplicity calculation based on new modelings II.	Guided practical activity	2 Hours
Fit of experimental prompt neutron spectrum data with Maxwellian and Watt spectra.	Guided practical activity	2 Hours
Modeling of prompt neutron spectrum using the most-probable fragmentation approach.	Guided practical activity	2 Hours

References:

1. C.Wagemans (editor) ”The nuclear fission process” CRC Press, USA, 1991.
2. G.Vladuca ≪ Elemente de fizica nucleara, partea a II-a ≫, Ed.Univ.Buc., 1990.
3. A.Berinde, G.Vladuca ≪ Reactii nucleare neutronice in reactor ≫ Ed.Teh.Buc., 1978.
4. A.Tudora, E.Sartori ”Biblioteci de date nucleare si coduri de calcul din domeniul nuclear ≫, Ed.Univ. Buc.1999
5. D.G.Madland, J.R.Nix, Nucl.Sci.Eng. (1982) 213-271.
6. A.Tudora and F.-J.Hambsch, Eur.Phys.J.A 53 (2017) 159.
7. IAEA (www.iaea.org), IAEA Nuclear Data Section (www-nds.iaea.org):nuclear data libraries EXFOR, RIPL, ENDF

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

In order to sketch the contents, to choose the teaching / learning methods, taking into account the high importance of this discipline in e.g. the field of energy (nuclear power plants) of propulsion (nuclear reactors for propulsion), medicine etc., the holders of the discipline have consulted the content of similar disciplines taught in universities of abroad (Ecole Politechnique de Paris, Université de Bordeaux, Université Paris-Sud etc.). The content of the discipline is in agreement with the requirements of employment in research institutes in nuclear physics and engineering, nuclear power plants, medical laboratories, which use nuclear methods in investigation and treatment (according to the law).

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 analyze specific examples	Oral examination	40%
Practical	- ability to use specific methods to solve a given problem. - ability to analyze the obtained results - knowledge and use of programming languages and numerical methods needed for the realization of computer codes for modeling and for the processing of experimental data.	Homeworks / writen tests	60%
Minimal requirements for passing the exam	Correct understanding of the concepts and phenomena, the ability to work in a team and to obtain accurate numerical results on topics imposed. • Finalization of the tasks given during the practical activities. • Correct exposure of the subjects, which minimally required to obtain 5 at the oral examination.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Marius CĂLIN	Lect. Dr. Marius CĂLIN

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

Syllabus

Academic year 2025/2026
DO.203.2 Radioactive beams, nuclear bosonic condensation, and new types of nuclei

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Radioactive beams, nuclear bosonic condensation, and new types of nuclei						
2.2. Teacher	Lect. Dr. Marius Calin						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Marius Calin						
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DS

3. Total estimated time

3.1. Hours per week	3	3.2. Lectures	1	3.3. Tutorials/Practicals/Projects	0/2/0
3.4. Total hours per semester	42	3.5. Lectures	14	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	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	Mathematical Analysis, Theoretical Mechanics, Optics, Atomic Physics, Nuclear Physics, Particle Physics, Electrodynamics, Statistical Physics, Experimental Methods in Nuclear Physics
4.2. competences	Programming Languages: FORTRAN, C++ ; Matlab, Programs for processing images and time series; Numerical Methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Seminar room/Amphitheater with multimedia features (laptop/PC, video projector, internet access)
5.2. for tutorials/practicals	Practical classes room with multimedia features (laptops/PCs, video projector, internet access), specific simulation codes, detectors, electronic units for signal processing, software for experimental data analysis (Minuit, Origin, etc.), collaboration with IFIN-HH and ISS experimental teams

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R6. The student/graduate understands the fundamental concepts of modern cosmology and astrophysics, including the structure and evolution of the Universe, galaxy formation, and primordial nucleosynthesis. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R6. The student/graduate analyzes and interprets data from observations and numerical simulations, using theoretical models to describe cosmological and astrophysical phenomena. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R6. The student/graduate demonstrates initiative and autonomy in exploring topics in cosmology and astrophysics, contributing to research or science outreach activities, and integrating acquired knowledge in interdisciplinary contexts. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Open problems in Nuclear and Particle Physics. Ways and methods for investigations	Systematic exposition - lecture. Heuristic conversation. Examples.	1 Hour
Radioactive beams. Fundamental aspects. Ion sources and accelerators. Obtaining methods for radioactive beams productions. Existing facilities and experiments (Lise 3, Sissi, spiral etc.). High energy radioactive beams (ISOLDE, R3B, BECQUEREL etc.)	Systematic exposition - lecture. Heuristic conversation. Examples.	3 Hours
Exotic nuclei. Spectroscopy of exotic nuclei. Investigation of the nuclear reaction mechanisms and search for new information on the nuclear structure	Systematic exposition - lecture. Heuristic conversation. Examples.	2 Hours
Applications of the radioactive beams in solving problems in Nuclear Physics, Nuclear Astrophysics, Solid State Physics, Nuclear Medicine and Nuclear Therapy etc.	Systematic exposition - lecture. Heuristic conversation. Examples.	2 Hours
Clustering in Nuclear Physics processes and phenomena: From cumulative effect to Bose-Einstein condensation of alpha particles	Systematic exposition - lecture. Heuristic conversation. Examples.	1 Hour
Pionic and kaonic condensation and Migdal's point of view	Systematic exposition - lecture. Heuristic conversation. Examples.	1 Hour
Clusters formation in nuclear matter at different thermodynamic parameters.	Systematic exposition - lecture. Heuristic conversation. Examples.	1 Hour
Bose-Einstein condensation of alpha particles in a multi-component environment. Phenomenology and experiments. Connections with nuclear and cosmological processes	Systematic exposition - lecture. Heuristic conversation. Examples.	2 Hours
Alpha particles condensation and stellar evolution. Neutron stars. Perspectives	Systematic exposition - lecture. Heuristic conversation. Examples.	1 Hour

References:

1. A Das and T. Ferbel - Introduction to Nuclear and Particle Physics, World Scientific, Second edition, 2005
2. K.Heyde – Basic Ideas and Concepts in Nuclear Physics – IOP Bristol and Philadelphia , 1999
3. K. Bethge (editor) - Experimental Methods in Heavy Ion Physics - Lectures Notes in Physics 83(1978)1-251
4. R. Prasad, B.P. Singh – Fundamentals and Applications of Heavy Ion Collisions (Below 10 MeV/Nucleon Energies) – Cambridge University Press, 2018 (318 pages)
5. Stefaan Tavernier - Experimental Techniques in Nuclear and Particle Physics – Springer - Springer Heidelberg Dordrecht London New York, 2010 (312 pages)
6. Richard F. Casten - Nuclear Structure from a Simple Perspective, 2001 (ISBN-13: 9780198507246; DOI: 10.1093/acprof:oso/9780198507246.001.0001)
7. Y.G. Ma et al - http://arxiv.org/ftp/nucl-ex/papers/0410/0410019.pdf
8. K. Hagino, Tanihata et al - http://arxiv.org/1208.1583
9. Al.Jipa, C.Beşliu – Elemente de Fizică nucleară relativistă. Note de curs, Editura Universităţii din Bucureşti, 2002
10. D. Blaschke, N.K. Glendenning, A. Sedrakian - Physics of Neutron Star Interiors, Springer Verlag, 2001
11. Xin-Hui Wu, Si-BoWang, Armen Sedrakian, Gerd Röpke - Composition of Nuclear Matter with Light Clusters and Bose–Einstein Condensation of α Particles – Journal of Low Temp Phys, 2017
DOI 10.1007/s10909-017-1795-x
12. Y Blumenfeld, T Nilsson, P Van Duppen - Facilities and methods for radioactive ion beam production - Phys. Scr. T152(2013)014023 (24pp) doi:10.1088/0031-8949/2013/T152/014023
13. Alex C. Mueller – An overview of radioactive ion beams facilities – Proceedings of EFAC, Vienna, Austria, 2000
14. Isao Tanihata – Radioactive beam science, past, present, future – Nuclear Instruments and Methods in Physics Research B266(2008)4067-4073
15. A. Griffin, D.W. Snoke, S. Stringari (editors) – Bose-Einstein Condensation – Cambridge University Press, 2002 (electronic edition)

7.3 Practicals	Teaching techniques	Observations
Production methods of radioactive beams - in collaboration with NFD from IFIN-HH	Practical activity	6 Hours
Presentation of the experimental set-ups for the study of radioactive beams - in collaboration with NFD from IFIN-HH	Practical activity	6 Hours
Analysis of the experimental data for characterization of the radioactive beams	Practical activity	2 Hours
Study of the different spectra obtained in experiments with radioactive beams - in collaboration with NFD from IFIN-HH	Practical activity	4 Hours
Pionic and kaonic condensation in high energy heavy ion collisions	Practical activity	2 Hours
Cluster condensation in experiments with nuclear emulsions - in collaboration with ISS	Practical activity	4 Hours
Simulations for alpha particle condensation in different nuclei	Practical activity	4 Hours

References:

https://cern.ch/
http://gsi.de/
http://jinr.ru/
The recommended bibliography for course

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 forms/develops some theoretical competences and/or abilities that are important/fundamental for the student that graduate in the domain of the Modern Physics, in agreement with the national and European/international standards. The contents and the teaching methods have been selected after a careful and detailed analysis of the specific course units from the curricula of different important Universities from Europe and United (University of Oxford, University of Parma, University of Padova, University of California, University of Frankfurt, university of Darmstadt (see, for example https://www.ox.ac.uk/admissions/undergraduate/courses-listing?wssl=1, http://www.difest.unipr.it/it/didattica/laurea-triennale-fisica/calendario-didattico, http://en.didattica.unipd.it/didattica/2015/SC1158/2014)) The course structure and content are in agreement with the requirements and expectations of the possible employers (Higher Education, Research, Industry etc.)

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- The right consideration on the subject extracted at examination. - Clarity and coherence of presentation - Right utilization of the models, formulae and relationships in calculation of the physical quantities - Personal computing programs realized for a given subject	Oral examination	60%
Practical	- Ability for analyzing of the experimental or simulated data and the capacity to evaluate the obtained results and good description of the used methods at the practical classes evaluation - Periodic testing - Continuum testing during the semester - Homework solving during the semester	Short reports on the work	40%
Minimal requirements for passing the exam	Obtaining the minimal average mark 5 Knowledge of the fundamental notions and subjects form the course syllabus Obtaining the mark 10 Good knowledge of notions from the course content, achievement of the requests at the practical classes and verification of the works at practical classes		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Marius Calin	Lect. Dr. Marius Calin

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

Syllabus

Academic year 2025/2026
DO.204.1 Nuclear magnetic resonance. Physical principles and applications

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Nuclear magnetic resonance. Physical principles and applications
2.2. Teacher	Conf.univ.dr. Vasile Bercu
2.3. Tutorials/Practicals instructor(s)	Conf. univ. dr. Vasile Bercu

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

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	45
Research in library, study of electronic resources, field research	25
Preparation for practicals/tutorials/projects/reports/homework	49
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 deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R7. The student/graduate uses computing codes or software packages for research topics and specific applications.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Fundamentals of magnetic resonance physics: macroscopic description of magnetic resonance, quantum treatment of spin systems in magnetic field, spin-spin and spin-lattice interactions and corresponding relaxation times.	Systematic exposition - lecture, demonstration, discussion, case study. Examples	6 Hours
Relaxation processes in magnetic resonance: Bloch equations, relaxation mechanisms, resonance line.	Systematic exposition - lecture, demonstration, discussion, case study. Examples	4 Hours
Interactions of electron paramagnetic centers, the Spin Hamiltonian: Zeeman interaction, interaction with crystal electric field (fine structure of resonance spectra), interaction with magnetic moments of own nuclei and nuclei of neighboring atoms,dipole interaction.	Systematic exposition - lecture, demonstration, discussion, case study. Examples	4 Hours
Applications of Electron Paramagnetic Resonance: Dosimetry retrospective geochronology and food science	Systematic exposition - lecture, demonstration, discussion, case study. Examples	6 Hours
Advanced electron paramagnetic resonance techniques: EPR at multiple fields and frequencies, puls EPR	Systematic exposition - lecture, demonstration, discussion, case study. Examples	4 Hours
Local interactions of nuclear magnetic centers: Chemical shift and indirect nuclear dipolar interaction	Systematic exposition - lecture, demonstration, discussion, case study. Examples	4 Hours

References:

1.A. Carrington, A.D.McLachlan, Introduction to magnetic resonance with applicayion to chemistry and chemicalphysics, Harper and Row, 1967
J.R. Bolton, J.A.Weil, Electron paramagnetic resonance : elementary theory and practical aplications, John Wiley and Sons, Inc., Hoboken, New Jersey, 2007
C.P. Slichter, Principle of magnetic resonance, Springer Verlag Berlin Heidelberg GmbH, 1978
A. Abragam, B. Bleaney, Electron Paramagnetic Resonance of Transition Ions, Oxford University Press, 1970
M. Ikeya, New applications of electron spin resonance: Dating, Dosimetry and Microscopy, World Scientific, 1993
R.G. Saifutdinov, L.I. Larina, T.I. Vakul'skaya, M.G. Voronkov, Electron Paramagnetic Resonance in Biochemistry and Medicine, Kluwer Academic Publisher, 2002
G.R. Eaton, S.S. Eaton, D.P. Barr, R.T. Weber, (eds.) Quantitative EPR, Springer, 2010
A. Lund, M. Shiotani (eds.) Applications of EPR in Radiation Research, Springer, 2014

7.3 Practicals	**Teaching techniques**	**Observations**
Paramagnetic electron resonance spectrometer setup: signal dependence on modulation amplitude, microwave radiation power	Lecture. Debate. Examples. Guided practical activity.	6 Hours
Analysis of free radicals generated by irradiation with ionizing radiation: irradiated foods	Guided practical activity.	2 Hours
Analysis of free radicals in liquids	Guided practical activity.	2 Hours
Analysis of the Mn2+ ion in calcium carbonate	Guided practical activity.	2 Hours
Analysis of the Pb3+ ion in calcium carbonate	Guided practical activity.	2 Hours

Treatment of the H atom in an external magnetic field	Lecture. Debate.Guided practical activity.	4 Hours
Interactive Cu2+ ion analysis in multiple fields and by the pulse technique	Guided practical activity.	4 Hours
Processing and simulation of electron paramagnetic resonance spectra	Guided practical activity.	6 Hours

References:

A. Carrington, A.D.McLachlan, Introduction to magnetic resonance with applicayion to chemistry and chemical physics, Harper and Row, 1967
J.R. Bolton, J.A.Weil, Electron paramagnetic resonance : elementary theory and practical aplications, John Wiley and

Sons, Inc., Hoboken, New Jersey, 2007
C.P. Slichter, Principle of magnetic resonance, Springer Verlag Berlin Heidelberg GmbH, 1978
A. Abragam, B. Bleaney, Electron Paramagnetic Resonance of Transition Ions, Oxford University Press, 1970
M. Ikeya, New applications of electron spin resonance: Dating, Dosimetry and Microscopy, World Scientific, 1993
A. Schweiger, G. Jeschke, Principles of Pulse Electron Paramagnetic Resonance, Oxford University Press, 2001
C.D. Negut,M. Cutrubinis, ESR Standard Methods for Detection of Irradiated Food, în: A. K. Shukla (ed.) Electron Spin Resonance in Food Science, Elsevier, Academic Press (2017)
O.G. Duliu, V. Bercu, ESR Investigation of the Free Radicals in Irradiated Foods, în: A. K. Shukla (ed.) Electron Spin Resonance in Food Science, Elsevier, Academic Press (2017)
O.G. Duliu, V. Bercu, D. Neguţ, Mn2+ EPR spectroscopy for the provenance study of natural carbonates, în: A. K. Shukla (ed.) Electron Magnetic Resonance - Applications in Physical Sciences and Biology, Elsevier, Academic Press (2019)

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

To identify the contents and the choice of teaching/learning methods, the holders of the subject consulted the contents of similar subjects taught at universities in the country and abroad such as the Swiss Federal Institute of Technology in Zurich (ETH Zurich), Universita degli studi di Padova, University of Southern California. The content of the discipline is according to the employment requirements in research institutes in physics and in education

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Knowledge of the fundamental notions - Appropriate achievement and correct understanding of the topics lectured in the course; - Demonstration of theoretical concepts correctly using the calculus equations; - Clarity, coherence and conciseness of the presentation; - The correct use of the studied physical models, formulas and calculus equations; - Ability to exemplify;	Examination of theoretical knowledge - written exam	50%
Practical	To familiarize oneself with specific experimental techniques and infrastructure To apply specific methods for solving a given exercise To interpret results	Colloquium examination	50%
Minimal requirements for passing the exam	Successful completion of all laboratory work, obtaining a grade of 5 in the colloquium and a grade of 5 in the written exam.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf.univ.dr. Vasile Bercu	Conf. univ. dr. Vasile Bercu

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

Syllabus

Academic year 2025/2026
DO.204.2 Atomic and molecular clusters

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Atomic and molecular clusters						
2.2. Teacher	Conf.univ.dr. Vasile Bercu						
2.3. Tutorials/Practicals instructor(s)	Conf. univ.dr. Vasile Bercu						
2.4 Year of study	2	2.5. Semester	1	2.6. Type of evaluation	exam	2.7.Classification	DA

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					40
Research in library, study of electronic resources, field research					39
Preparation for practicals/tutorials/projects/reports/homework					40
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	Atomic and Molecular Physics, Quantum Mechanics, Optics, Spectroscopy
4.2. competences	Use of software packages for data analysis

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia facilities classroom
5.2. for tutorials/practicals	Multimedia facilities classroom, Computer network

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R7. The student/graduate uses computing codes or software packages for research topics and specific applications.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Methods for deriving atomic clusters. Cluster characterization by mass spectrometry.	Systematic exposition - lecture. Examples	8 Hours
Atomic cluster description based on electronic structure, binding energy, "jelium" type magic numbers, semiempirical methods and density functional theory	Systematic exposition - lecture. Examples	8 Hours
Molecular clusters, formation in host mediums, optical transitions, assembly and formation of comples nanosystems, current applications în biophysics and energy conversion	Systematic exposition - lecture. Examples	6 Hours
Collective excitations in metallic and semiconducting clusters, plasmons, molecular spectrometry applications in characterizing biological samples and cell aggregation	Systematic exposition - lecture. Examples	6 Hours

References:
Atomic and Molecular Clusters , Ray.Johnston Tayler and Francis 2002
Bransden B. , Joachain C.J. Physics of Atoms and Molecules, Longman, 1986
Bernstein, E. R. Atomic and molecular clusters, Elsevier, 1990
Haberland H., Clusters of Atoms and Molecules I: Theory, Experiment, and Clusters of Atoms, Springer 1994

7.3 Practicals	Teaching techniques	Observations
Equilibrium configurations for Na, C and Si clusters. Binding energy calculation	Practical activity	4 Hours
Dynamic analysis models based on semiempirical potentials	Practical activity	4 Hours
Optical transitions in large ensembles of metal atoms. Plasmons in Au and Ag nanopowders organized in organic grid	Practical activity	4 Hours
Plasmon spectrometry on nanopowders biological samples employing the "on-chip spectrometry" technique	Practical activity	4 Hours
Absorbtion band analysis of water molecular clusters in mesoporous media and in SiOx gels as a function of temperature.	Practical activity	2 Hours
Study of molecular cluster formation of surfactants with spectrophotometric probe.	Practical activity	2 Hours
Water molecular clusters în hydrocarbons în 20-90C domain.	Practical activity	2 Hours
Atomic model clusters for vibrational analysis of biocompatible phosphosilicate glasses. P=O and P-O population analysis.	Practical activity	2 Hours
Clusterization processes by "on-chip spectrometry" technique for surfatants and bio-cells.	Practical activity	2 Hours
Light scattering on bio-cells. Optical and geometrical parameter extraction.	Practical activity	2 Hours

References:
Atomic and Molecular Clusters , Ray.Johnston Tayler and Francis 2002
Bransden B. , Joachain C.J. Physics of Atoms and Molecules, Longman, 1986
Bernstein, E. R. Atomic and molecular clusters, Elsevier, 1990
Haberland H., Clusters of Atoms and Molecules I: Theory, Experiment, and Clusters of Atoms, Springer 1994
Tsukuda T., Hakkinen H., Protected Metal Clusters: From Fundamentals to Applications, Elsevier, 2015

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

In order to sketch the contents, to choose the teaching / learning methods, given the special importance of the discipline for applications in modern physics and technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad.

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/analyse specific examples	Oral examination	50%
Practical	- ability to use specific experimental methods/apparatus - ability to perform/design specific experiments - ability to present and discuss the results	Colloquium	50%
Minimal requirements for passing the exam	Correct understanding of the concepts and phenomena, the ability to work with them and obtain accurate numerical results on topics imposed. Requirements for mark 5 Carrying out all the activities during the semester.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf.univ.dr. Vasile Bercu	Conf. univ.dr. Vasile Bercu

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

Syllabus

Academic year 2025/2026
DO.208.1 Spectroscopic methods and techniques for investigation of the nuclear and subnuclear systems

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Spectroscopic methods and techniques for investigation of the nuclear and subnuclear systems						
2.2. Teacher	Lect. Dr. Radu Alin Vasilache						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Radu Alin Vasilache						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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	30	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	0/10/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					48
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					95
3.8. Total hours per semester					125
3.9. ECTS					5

4. Prerequisites (if necessary)

4.1. curriculum	Study of the courses Physics of the Atomic Nucleus, Interactions of the ionizing particles with matter Interacţiile radiaţiilor ionizante cu materia, Methods of Detection, Special Relativity Theory, Quantum Physics
4.2. competences	Knowledge on the use of nuclear apparatus, data analysis and processing, identifying sources of information

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Digital videoprojector / HD display
5.2. for tutorials/practicals	Laboratory apparatus: HV sources, signal generators, oscilloscopes, electrometers, multichannel analyzers, NIM amplifiers, NIM timer / scaler, NIM SCA, NIM Bin, computer.

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Introduction – general properties of radiation detectors. Spectroscopic detectors and their general properties	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours
Scintillation detectors. Inorganic and organic scintillators. Scintillation processes. Scintillation signal processing. Characteristics of scintillation detectors. Resolution, pulse shape, and timing properties. Spectrometry with scintillation detectors.	Systematic presentation - lecture. Heuristic conversation. Examples	4 Hours
Semiconductor detectors. Types of semiconductor detectors and applications in spectrometry. SSB, PIPS, and SiLi detectors. Construction/production of semiconductor detectors. Characteristics of semiconductor detectors.	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours
HPGe semiconductor detectors. HPGe detector configurations. Operational characteristics of HPGe detectors. Resolution, pulse shape, and timing properties. Applications in gamma spectrometry.	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours
Gamma and X-ray spectrometry. Applications. Calibration of gamma spectrometers. Calibration of spectrometers in energy. Response function. Calibrations in efficiency. Calibration methods. Factors influencing the efficiency of a measurement chain. Design of a gamma spectrometer. Selection of the measurement chain according to the application. Absolute and relative measurements. Reference materials. Intercomparisons. Applications in dating. Applications in the characterization of radioactive waste. Measurement of half-lives: the decay curve method. The delayed coincidence method. The Doppler shift method. Other methods. Ultra-low background measurements. Internal dosimetry using gamma spectrometry	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours
Alpha and heavy charged particle spectrometry. Applications. Alpha, proton, and deuteron particle spectrometry. Energy straggling and range straggling. Energy resolution and response function of alpha detectors. Energy calibration. Preparation of samples for measurement. Efficiency calibration. Heavy ion spectrometry (Z larger than 2). Pulse amplitude defect. Energy calibration. Schmitt method. Preparation of calibration sources. Time-of-flight spectrometry. EdE/dx telescopes. Space resolution detectors	ESystematic presentation - lecture. Heuristic conversation. Examples	2 Hours
Beta and electron beam spectrometry. Applications. Electron beam spectrometry using solid detectors. Electron backscattering. Resolution of electron detectors and response function. Calibration of beta spectrometers. Beta spectrometry using liquid scintillators. LSC principles. Beta spectrum. Composite beta spectra. Interference. Factors affecting the LSC beta spectrum. Quenching and counting efficiency.	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours

Neutron detection and spectrometry. Neutron interaction with matter. Types of neutron interactions: scattering and absorption. Effective cross sections of neutron-induced reactions. Neutron flux. Interaction rates with polyenergetic neutrons. Neutron spectrometry. Slow neutron detection. Reactions used in neutron detection. Boron detectors. He detectors. Li-6 detectors. Fission chambers; activation detection; other reactions used. Fast neutron detection. Neutron spectrometry. Detection based on moderation. Bonner spheres. Detection and spectrometry based on activation reaction thresholds. Detection and spectrometry based on the recoil proton spectrum. Neutron spectrometry using crystal spectrometers. Time-of-flight (ToF) spectrometers.	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours
Applications of nuclear spectroscopy: from natural radioactivity and the study of exotic isotopes to medicine, geology, materials science, and forensics.	Systematic presentation - lecture. Heuristic conversation. Examples	2 Hours

References:

1. G.Vlăducă, Elemente de fizică nucleară I, II , Ed.Univ.Buc., 1989, 1990
2. G. Vlăducă, R. Ion-Mihai, Spectroscopie nucleara, Ed. Universitatii din Bucuresti
3. G.F. Knoll, Radiation Detection and Measurement, John Wiley and Sons Inc., New York, 1989
4. N. Tsoulfanidis, S, Landsberger, Measurement and Detection of Radiation, 4th Edition, CRC Press, 2015
5. W.R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer, Berlin-Heidelberg, 1994
6. J. Kantele, Handbook of Nuclear Spectrometry, Academic Press, 1995
7. Note de curs
8. capitole recomandate din cursuri şi cărţi accesibile on-line

7.3 Practicals	**Teaching techniques**	**Observations**
NaI(Tl), CZT, HPGe detectors – properties, parameters.	Practical exercise. Examples	2 Hours
Energy and FWHM Calibrations of gamma spectrometers	Practical exercise. Examples	1 Hour
Efficiency calibrations of gamma spectrometers for various measuring scenarios using LABSocs / ISOCS	Practical exercise. Examples	2 Hours
Efficiency calibrations of gamma spectrometers using standard sources	Practical exercise. Examples	1 Hour
Analysis of gamma spectra obtained for various geological samples	Practical exercise. Examples	2 Hours
Nuclear forensics measurements - methods to evaluate U enrichment	Practical exercise. Examples	2 Hours

References:

1. G.F. Knoll, Radiation Detection and Measurement, John Wiley and Sons Inc., New York, 1989
2. W.R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer, Berlin-Heidelberg, 1994
3. J.W. D. Hamilton, ed., The electromagnetic interaction in nuclear spectroscopy
4. Romanian Reports in Physics 68 (2016) Supplement – ELI-NP Technical Design Reports
5. IAEA TRS 398

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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in medicine and medical research, the professors of the discipline consulted the content of similar disciplines taught at universities in the country and abroad (Oxford University, International Atomic Energy Agency, European Federation of Organisations for Medical Physics, European Association for Nuclear Medicine, etc.). The content of the discipline is in accordance with the requirements for employment in research institutes in nuclear physics, nuclear energy (NPPs) sector, nuclear forensics / safeguards and industry.

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	Oral exam and assessment	70%
Practical	- Knowledge and use of experimental techniques - Interpretation of the results - Problem solving	Laboratory colloquium	30%
Minimal requirements for passing the exam	Completion of all laboratory work and grade 5 in the laboratory and tutorials colloquium The correct exposure of the indicated subjects at least at qualitative level to obtain a score of 5 in the final exam.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Radu Alin Vasilache	Lect. Dr. Radu Alin Vasilache

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

Syllabus

Academic year 2025/2026
DO.208.2 Properties of atomic and molecular systems. Experimental models and techniques

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Properties of atomic and molecular systems. Experimental models and techniques						
2.2. Teacher	Conf.univ.dr. Vasile Bercu						
2.3. Tutorials/Practicals instructor(s)	Conf. univ.dr. Vasile Bercu						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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	30	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	0/10/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					35
Research in library, study of electronic resources, field research					25
Preparation for practicals/tutorials/projects/reports/homework					35
Tutorat					0
Other activities					0
3.7. Total hours of individual study					95
3.8. Total hours per semester					125
3.9. ECTS					5

4. Prerequisites (if necessary)

4.1. curriculum	Atomic and Molecular Physics, Quantum Mechanics, Spectroscopy
4.2. competences	Programming

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia facilities classroom
5.2. for tutorials/practicals	Laboratory

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R7. The student/graduate uses computing codes or software packages for research topics and specific applications.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Modelling atomic and molecular systems: Molecular dynamics, Hartree-Fock and DFT methods.	Systematic exposition - lecture. Examples	6 Hours
Photon-molecule interaction and UV-Vis, IR, microwaves molecular spectra analysis.	Systematic exposition - lecture. Examples	6 Hours
Current applications of atomic systems models for nanometric structures and analysis methods.	Systematic exposition - lecture. Examples	4 Hours
Thermoluminescent processes, retrospective dosimetry and geocronology. Interactions of ions with solid state matter. Rutherford backscattering.	Systematic exposition - lecture. Examples	4 Hours

References:
B. H. Bransden, Charles J. Joachain, Physics of Atoms and Molecules, Addison-Wesley, 2003
Erza G.S., Symmetry principles of molecules, Springer-Verlag, 1982
Cowen R.D. The theory of the atomic structure and spectra, University of California Press, 1981

7.3 Practicals	Teaching techniques	Observations
Hartree-Fock method: Multi-electronic integral calculations, convergence criteria, wavefunction analysis, total charge density distribution calculation in closed shell systems.	Practical activities	2 Hours
Atomic cluster models for FTIR spectra analysis of C and Si local vibrations. Correlation with direct measurements.	Practical activities	2 Hours
Optical transitions în benzene molecule; HF calculations and molecular spectrum	Practical activities	2 Hours
Atomic cluster models for simulating the interaction of atomic and molecular hydrogen with graphitic surfaces.	Practical activities	2 Hours
Thermoluminescent emission of defects induced by ionizing radiation in TiO2.	Practical activities	2 Hours

References:
B. H. Bransden, Charles J. Joachain, Physics of Atoms and Molecules, Addison-Wesley, 2003
Erza G.S., Symmetry principles of molecules, Springer-Verlag, 1982
Cowen R.D. The theory of the atomic structure and spectra, University of California Press, 1981

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

In order to sketch the contents, to choose the teaching / learning methods, given the special importance of the discipline for applications in modern physics and technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad.

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/analyse specific examples	Writen examination	50%
Practical	- ability to use specific experimental methods/apparatus - ability to perform/design specific experiments - ability to present and discuss the results	Coloquium	50%

Minimal requirements for passing the exam	Requirements for mark 5 Carrying out all the activities during the semester with obtaining mark 5 by summing the points obtained at the activities during the course and examination, according to the weights specified

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf.univ.dr. Vasile Bercu	Conf. univ.dr. Vasile Bercu

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

Syllabus

Academic year 2025/2026
DO.209.1 Lasers, plasma, and acceleration methods. Experimental applications at ELI-NP

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Lasers, plasma, and acceleration methods. Experimental applications at ELI-NP
2.2. Teacher	CS3 Dr. Mihai Straticiuc, CS2 Dr. Ovidiu Teşileanu
2.3. Tutorials/Practicals instructor(s)	CS3 Dr. Mihai Straticiuc, CS2 Dr. Ovidiu Teşileanu

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

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	30	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	0/10/0

Distribution of estimated time for study	
Learning by using one's own course notes, manuals, lecture notes, bibliography	48
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	95
3.8. Total hours per semester	125
3.9. ECTS	5

4. Prerequisites (if necessary)

4.1. curriculum	Previously attended courses of Electricity and Magnetism, Optics, Mathematics, Atomic Physics, Nuclear Physics, Programming Languages
4.2. competences	Problem solving, use of the computer

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Classroom (with multimedia facilities)
5.2. for tutorials/practicals	Experimental setups from the Laboratories of IFIN-HH, Tandem accelerators of IFIN-HH, desktop or laptop computers

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R7. The student/graduate uses computing codes or software packages for research topics and specific applications.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Short history and present status of particle accelerators development: classification. Applications: industry, medicine.	Systematic exposition - lecture. Examples	4 Hours
Particle sources (electrons, ions)	Systematic exposition - lecture. Examples	2 Hours
Transverse beam dynamics (emittance)	Systematic exposition - lecture. Examples	2 Hours
Longitudinal beam dynamics	Systematic exposition - lecture. Examples	2 Hours
Presentation of the ELI-NP project. Description of the generated beams and complex equipment	Systematic exposition - lecture. Examples	2 Hours
Laser pulses as particle accelerators	Systematic exposition - lecture. Examples	2 Hours
Experiments of physics and astrophysics with particles accelerated with laser pulses. Applications.	Systematic exposition - lecture. Examples	2 Hours
Experiments with gamma photons generated by Laser Compton Scattering (LCS). Applications.	Systematic exposition - lecture. Examples	2 Hours
Detectors developed at ELI-NP. Obtaining ultra-high levels of vacuum.	Systematic exposition - lecture. Examples	2 Hours

References:

E. Wilson, An Introduction to Particle Accelerators, Oxford University Press, 2001
H. Wiedemann, Particle Accelerator Physics, 3rd Edition, Springer Berlin Heidelberg New York, 2007
S. Baird, Accelerators for Pedestrians, AB-Note-2007-014 OP, 2007
CERN Accelerator School Proceedings http://cas.web.cern.ch/cas/CAS_Proceedings.html
B. Wolf, Handbook of Ion Sources 1st Edition, CRC Press, 1995
Dabu, Razvan, Lumina extrema. Lasere de mare putere, Ed. Academiei Romane, 2015
McMahon, Quantum Field Theory Demystified McGraw-Hill Companies 2008
Vacuum Technology - http://www-eng.lbl.gov/ shuman/NEXT/REFs/Vacuum-Technology.pdf

7.3 Practicals	**Teaching techniques**	**Observations**
Using ion beams for elemental analysis and simulating a radiobiology experiment using the numerical code Fluka	Problem solving	2 Hours
Generation of ultra-short laser pulses – HPLS system at ELI-NP	Problem solving	1 Hour
Physical theories for ultra-high intensity fields	Problem solving	2 Hours

Determining the elemental composition of an artefact using the PIXE method (Particle Induced X-ray Emission)	Guided practical work	2 Hours
Measurement of thin films thickness using the RBS method (Rutherford Backscattering Spectrometry)	Guided practical work	1 Hour
Numerical simulation techniques for electron acceleration with laser pulses	Guided practical work	2 Hours

References:

M. Nastasi, J. Mayer, Y. Wang, Ion Beam Analysis, Fundamentals and Applications, 2015
J. R. Bird, J. S. Williams, Ion Beams for Materials Analysis, 1989
S. Johansson, J. Campbell, K. Malmqvist, Particle-Induced X-ray Emission Spectrometry (PIXE), 1995
Dabu, Razvan, Lumina extrema. Lasere de mare putere, Ed. Academiei Romane, 2015
R.W. Hockney, J.W.Eastwood, Computer simulation using particles, IOP Publishing 1988
C.K. Birdsall, A. Langdon, Plasma physics via computer simulation, Cambridge University Press, 1991
Greiner, Reinhardt, Quantum Electrodynamics, Springer 2009
Peskin, Schroder, An introduction to QFT, Perseus Books 1995
Schwartz, Quantum Field Theory and the Standard Model, Cambridge University Press, 2014
Lahiri, Pal, A First Book of QFT, Narosa, 2004
McMahon, Quantum Field Theory Demystified McGraw-Hill Companies 2008

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

In order to sketch the contents, to choose the teaching / learning methods, given the special importance of the discipline for applications in modern physics and technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad. The content of the discipline is according to the requirements of employment in research institutes in nuclear physics and engineering, medical laboratories that use nuclear methods in investigation and treatment (according to the law).

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/analyze specific examples - application of acquired knowledge	Oral examination	70%
Practical	- ability to use specific problem solving methods - ability to use specific experimental methods/apparatus - ability to present and discuss the results	Homeworks / written tests Lab reports	30%
Minimal requirements for passing the exam	Minimal requirements for passing the exam Correct understanding of the concepts and phenomena, the ability to work with them and obtain accurate numerical results on topics imposed. Requirements for mark 5 (10 points scale) • Carrying out all the activities during the semester • Obtaining note 5 by summing the points obtained at the activities during the course and examination, according to the weights specified		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	CS3 Dr. Mihai Straticiuc, CS2 Dr. Ovidiu Teşileanu	CS3 Dr. Mihai Straticiuc, CS2 Dr. Ovidiu Teşileanu

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

Syllabus

Academic year 2025/2026
DO.209.2 Plasma physics in the study of nuclear, astrophysical, and cosmological processes

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Plasma physics in the study of nuclear, astrophysical, and cosmological processes						
2.2. Teacher	Lect. Dr. Marius Calin						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Marius Calin						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DS

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	30	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	0/10/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					48
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					95
3.8. Total hours per semester					125
3.9. ECTS					5

4. Prerequisites (if necessary)

4.1. curriculum	All previous compulsory subjects with a focus on Nuclear Physics, Particle Physics, Astrophysics, the Basics of higher Mathematics, Programming and use of simulation codes, elements of Mechanics and Quantum Physics, Thermodynamics and Statistical Physics, Electrodynamics and Theory of Relativity, Experimental Methods.
4.2. competences	Heavy ion physics, nuclear spectroscopy and nuclear reaction mechanisms

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Room with multimedia equipment (video projector)
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R6. The student/graduate understands the fundamental concepts of modern cosmology and astrophysics, including the structure and evolution of the Universe, galaxy formation, and primordial nucleosynthesis. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R6. The student/graduate analyzes and interprets data from observations and numerical simulations, using theoretical models to describe cosmological and astrophysical phenomena. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R6. The student/graduate demonstrates initiative and autonomy in exploring topics in cosmology and astrophysics, contributing to research or science outreach activities, and integrating acquired knowledge in interdisciplinary contexts. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Basic notions of plasma physics. Definition, plasma components and methods of obtaining classical plasmas	Systematic exposition - lecture. Examples	2 Hours
Types of plasmas. The fundamental parameters for the characterization of plasmas. Instabilities in the classical plasmas	Systematic exposition - lecture. Examples	3 Hours
Plasmas in Nuclear Physics. Nuclear fusion. Tokamak systems, the Lawson criterion and energy production.	Systematic exposition - lecture. Examples	3 Hours
Plasmas in stars. Stellar evolution and connections with plasma types. Gravitational plasmas	Systematic exposition - lecture. Examples	4 Hours
Relativistic and ultra relativistic heavy ion physics. Phase diagram of nuclear matter and connections with fundamental cosmological processes. The primordial explosion (Big Bang).	Systematic exposition - lecture. Examples	2 Hours
Scenarios of the evolution of the Universe. Stages in the evolution of the Universe that can be traced through relativistic nuclear collisions.	Systematic exposition - lecture. Examples	2 Hours
Connections between the properties of quark and glu-on plasmas/other types of nuclear matter plasmas with the properties of classical plasmas. Hypotheses for the introduction of similar parameters in nuclear matter plasmas. Comparisons	Systematic exposition - lecture. Examples	2 Hours
Plasma of quarks and gluons and the initiation of the hadronization process. Nucleosynthesis and stellar evolution. Hubble's Law in Cosmology and Relativistic Nuclear Physics. Perspectives.	Systematic exposition - lecture. Examples	2 Hours

References:
1. L.Tonks, I.Langmuir - Phys.Rev. 34(1929)876; L. Tonks - Am. J. Phys. 35(1967)857 2. R.J. Goldston, P.H. Rutherford – Introduction to Plasma Physics, CRC Press, 1995 3. Richard Fitzpatrick – An Introduction to Plasma Physics, CRC Press, 2014 4. Toader E., Popescu I.I, Cinetica si dinamica plasmei - Editura Ştiinţifică, Bucureşti 1983 5. Toader E et al, Fizica plasmei şi aplicaţii - Editura Ştiinţifică, Bucureşti 1981 6. C. Beşliu, Al. Jipa, Modele de structură nucleară şi mecanisme de reacţie – Editura Universităţii din Bucureşti, 2002 7. Al. Jipa, C.Beşliu, Elemente de Fizică nucleară relativistă. Note de curs – Editura Universitatii din Bucuresti, 2002 8. Anthony L. Peratt – Physics of the Plasma Universe – Springer Verlag New York Inc., 2014 9. Plasma and Space Physics - https://physics.dartmouth.edu/research/plasma-and-space-physics 10. Luis Conde - An Introduction to Plasma Physics and its Space Applications – IOP Bristol, London, 2020 11. James J.Y. Hsu - Visual and Computational Plasma Physics (https://doi.org/10.1142/9288) – World Scientific, Singapore, 2014 (pages: 428) 12. R A Treumann, W Baumjohann - Advanced Space Plasma Physics (https://doi.org/10.1142/p020), 1997 (pages: 392)

7.3 Practicals	Teaching techniques	Observations
Methods of characterization of plasma as the fourth state of matter.	Guided practical work Examples	1 Hour
Methods of plasma diagnosis	Guided practical work	1 Hour
Simulations with different codes to investigate the dynamics of relativistic nuclear collisions	Guided practical work	2 Hours
Analysis of common parameters for ”nuclear” plasmas and classical plasmas using simulation data and experimental results from Relativistic Nuclear Physics	Guided practical work	2 Hours
Identification of possible instabilities in the plasma of quarks and gluons using parameters from Plasma Physics	Guided practical work	2 Hours
Study of the dependence of specific parameters on the conditions of plasma formation	Guided practical work	2 Hours

References:
1. Lucrări practice de cinetica şi dinamica plasmei - Toader E. - Editura Universităţii din Bucureşti, 1982 2. Bazele spectroscopiei plasmei - Iova I., Popescu I.I., Toader E. - Editura Ştiinţifică, Bucureşti, 1987 3. Metode experimentale in fizica plasmei , Bratescu, G.G., and Toader E. - Editura Universităţii din Bucureşti 4. Elemente de Fizică nucleară relativistă. Note de curs – Al. Jipa, C.Beşliu - Editura Universitatii din Bucuresti, 2002 5. Elemente de Fizică nucleară relativistă. Note de seminar şi îndrumător de laborator – C.Beşliu, Al. Jipa, - Editura Universităţii din Bucureşti, 1999 6. Metode de identificare a particulelor elementare in Fizica energiilor inalte, Oana Ristea, Editura Universitatii din Bucuresti, 2020, ISBN: 978-606-16-1177-5

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 presentation - The correct use of calculation relations; - The ability to exemplify;	Oral examination	60%
Practical	- The application of specific methods of solving the given problem; - the ability to present, analyze and interpret the results;	Homework (problems)	40%

Minimal requirements for passing the exam	Obtaining the minimal average mark 5 The correct exposure of the subjects indicated for obtaining a score of 5 in the evaluation along the way and in the final exam.

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Marius Calin	Lect. Dr. Marius Calin

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

Syllabus

Academic year 2025/2026
DFC.107 Volunteering

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher	Lector. Dr. Marius Călin						
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	DC

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	Submission of a request (Annex 1 of the Regulation on Volunteer Credits within the University of Bucharest), addressed to the Dean and submitted to the Secretariat within 30 calendar days from the beginning of the semester. The host organization must be listed in the National NGO Register (www.just.ro/registrul-national-ong) or included in the list of validated host organizations at the Faculty of Physics.
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.
Responsibility and autonomy	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

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

The content of the subject is elaborated in accordance with the content of similar subjects taught at universities in the country and abroad. The content has been harmonized with the requirements imposed by employers in the field of industry, research, university and pre-university education of all degrees.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Project	- Running the volunteer internship. - Volunteer activity recognition file	The volunteer's activity report, in written format - Annex 2 of the Regulation on volunteer credits from the University of Bucharest. 50% Certificate issued by the host organization showing the number of volunteering hours completed, as well as a brief evaluation of the volunteer's activity - Annex 3 of the Regulation on volunteer credits from the University of Bucharest. 50%	100%
Minimal requirements for passing the exam	The existence of the volunteer's activity report as well as a Certificate issued by the host organization, indicating the number of volunteer hours completed and a brief evaluation of the volunteer's activity. The Volunteering Committee at the Faculty of Physics reviews the aforementioned documents and assigns the rating Accepted/Rejected.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lector. Dr. Marius Călin	

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

Syllabus

Academic year 2025/2026
DFC.112 Simulation codes in Nuclear Physics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Simulation codes in Nuclear Physics						
2.2. Teacher	Conf. dr. Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Conf. dr. Oana Ristea						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DA

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	Nuclear Physics, Relativistic nuclear physics, programming courses
4.2. competences	Use and development of computer codes for calculus and data analysis Ability to identify and exploit available information resources.

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia room equipped with internet connection and video-projector.
5.2. for tutorials/practicals	Multimedia room equipped with internet connection and video-projector, computers, specific codes.

6. Learning outcomes

Knowledge	R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.
Skills	R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.

Responsibility and autonomy	R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Basic notions about the Linux operating system.	Systematic exposition - lecture. Examples	2 Hours
Data processing in heavy ion physics experiments at relativistic energies.	Systematic exposition - lecture. Examples	2 Hours
Simulation codes used in relativistic nuclear physics field: HIJING and AMPT codes. Simulation of temporal evolution with UrQMD simulation code	Systematic exposition - lecture. Examples	4 Hours
ROOT program – histograms, graphics, Trees. Analysis of simulated data	Systematic exposition - lecture. Examples	8 Hours
Experimental data analysis in high energy physics. Particle identification	Systematic exposition - lecture. Examples	6 Hours
Comparison of simulated and experimental data. Examples	Systematic exposition - lecture. Examples	6 Hours

References:

ROOT User Guide - http://root.cern.ch/drupal/content/users-guide
Exemple de aplicaţii ROOT - http://root.cern.ch/drupal/content/howtos, http://root.cern.ch/drupal/content/example-applications
Manual Linux - http://www.debian.org/doc
Modelul UrQMD - http://urqmd.org
Modelul AMPT - https://karman.physics.purdue.edu/OSCAR/index.php/AMPT
Experimentul BRAHMS de la RHIC - http://www4.rcf.bnl.gov/brahms/WWW/brahms.html
Experimentul CBM de la FAIR - http://www.fair-center.eu/for-users/experiments/cbm.html
Ramona Vogt – Ultrarelativistic Heavy Ion Collisions, Elsevier Publishing, 2007
Al.Jipa, C.Beşliu – Elemente de Fizică nucleară relativistă. Note de curs, Editura Universităţii din Bucureşti, 2002
C.Beşliu, Al.Jipa – Elemente de Fizică nucleară relativistă. Note de seminar şi îndrumător de laborator, Editura Universităţii din Bucureşti, 1999

7.2 Tutorials	**Teaching techniques**	**Observations**
Conversion of Monte Carlo simulation codes output to ROOT Trees	Practical activity	4 Hours
Analysis of Trees in ROOT	Practical activity	4 Hours
Study of observables in the field of relativistic nuclear physics (transverse momentum, rapidity, pseudo-rapidity, apparent temperatures, etc.) using simulated data	Practical activity	8 Hours
Centrality and impact parameter for collisions of relativistic heavy ions. Analysis of simulated data	Practical activity	4 Hours
Experimental data analysis. Particle separation using TOF and RICH detectors	Practical activity	4 Hours
Comparison of simulated and experimental data. Examples	Practical activity	4 Hours

References:
ROOT User Guide - http://root.cern.ch/drupal/content/users-guide Exemple de aplicaţii ROOT - http://root.cern.ch/drupal/content/howtos, http://root.cern.ch/drupal/content/example-applications Manual Linux - http://www.debian.org/doc Modelul UrQMD - http://urqmd.org Modelul AMPT - https://karman.physics.purdue.edu/OSCAR/index.php/AMPT Experimentul BRAHMS de la RHIC - http://www4.rcf.bnl.gov/brahms/WWW/brahms.html Experimentul CBM de la FAIR - http://www.fair-center.eu/for-users/experiments/cbm.html Ramona Vogt – Ultrarelativistic Heavy Ion Collisions, Elsevier Publishing, 2007 Al.Jipa, C.Beşliu – Elemente de Fizică nucleară relativistă. Note de curs, Editura Universităţii din Bucureşti, 2002 C.Beşliu, Al.Jipa – Elemente de Fizică nucleară relativistă. Note de seminar şi îndrumător de laborator, Editura Universităţii din Bucureşti, 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

In order to sketch the contents, to choose the teaching/learning methods, given the special importance of the discipline for applications in modern high energy field physics, the teachers of the discipline consulted the content of similar topics/courses taught at universities in the country and abroad. The content of the discipline is in accordance with the requirements of employment in research institutes (according to the law).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- appropriate approach of the subject - coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyze specific examples	Oral examination	50%
Tutorial	- ability to use specific problem solving methods - ability to analyze the results	Oral examination Homeworks	50%
Minimal requirements for passing the exam	Minimal requirements for passing the exam Basic notions from the course content, meeting the requirements of the seminar activity Requirements for mark 10 (10 points scale) Good knowledge of all the topics from the course content		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. dr. Oana Ristea	Conf. dr. Oana Ristea

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

Syllabus

Academic year 2025/2026
DFC.113 Nuclear archaeology

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Nuclear archaeology						
2.2. Teacher	Lect. Dr. Marius CĂLIN						
2.3. Tutorials/Practicals instructor(s)	Lect. Dr. Marius CĂLIN						
2.4 Year of study	1	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DA

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	Atomic Physics, Nuclear Physics, Optics, Quantum Physics, Statistical Physics
4.2. competences	Programming languages, Processing of physical data and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Lecture hall (preferred, but not mandatory, multimedia equipment)
5.2. for tutorials/practicals	The experimental modules from the Nuclear Physics Laboratory, the Dosimetry Laboratory, the Computer Network (or individual laptops)

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R4. The student/graduate knows the fundamental concepts of dosimetry as well as the principles and rules of radiological protection. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology. R10. The student/graduate should know the norms and ethical principles regarding scientific research in the field, as well as develop a culture of responsibility in intellectual work.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R4. The student/graduate applies and evaluates safety and radiological protection regulations, applicable in educational and research laboratories. R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field. R10. The student/graduate should assimilate explicit norms (normative texts) or implicit ones (customs, practices) that regulate academic and research conduct in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R4. The student/graduate takes responsibility for complying with radiological protection norms and ethical standards in multidisciplinary teams. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community. R10. The student/graduate should demonstrate solidarity, responsiveness, and support for strengthening academic integrity.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
A brief introduction to nuclear archaeology. Description of nuclear processes that are applied in the dating and analysis of archaeological	Systematic presentation – lecture. Examples	2 Hours
Radiocarbon and K-40/Ar-40 method	Systematic presentation – lecture. Examples	2 Hours
Thermoluminescence dating method (TLD)	Systematic presentation – lecture. Examples	4 Hours
Optic stimulation luminescence dating method (OSL)	Systematic presentation – lecture. Examples	2 Hours
X-ray fluorescence (XRF) and particle-induced X-ray emission analysis (PIXE)	Systematic presentation – lecture. Examples	2 Hours
Rutherford backscattering (RBS) and particle recoil analysis	Systematic presentation – lecture. Examples	2 Hours
Moessbauer spectroscopy and electron spectroscopy for chemical analysis (ESCA)	Systematic presentation – lecture. Examples	2 Hours
Analysis of nuclear reactions and particle-induced gamma-ray emission (PIGE)	Systematic presentation – lecture. Examples	4 Hours

Mass spectrometry (AMS). Tomography. Summary and conclusions	Systematic presentation – lecture. Examples	2 Hours
Neutron activation analysis method. Principle and applications.	Systematic presentation – lecture. Examples	6 Hours

References:

1) G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000
2) W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003).
3) H.R. Verma, Atomic and Nuclear Analytical Methods, Springer Verlag, 2007
4) W. Loveland, D. Morrissey, G. Seaborg, Modern Nuclear Chemistry, Wiley, 2006
5) G. Artioli, Scientific methods and cultural heritage, Oxford University Press, 2010
6) H. Edwards, P. Vandenabeele, Analytical archaeometry, RSC Publishing, 2012

7.2 Tutorials	**Teaching techniques**	**Observations**
Radiocarbon dating	Systematic presentation	2 Hours
Analysis by X-ray fluorescence and PIXE	Systematic presentation	4 Hours
The use of thermoluminescence for dating archaeological objects	Systematic presentation	4 Hours
Moessbauer spectroscopy and analysis of tomograms	Systematic presentation	2 Hours
Neutron activation of a given sample and extraction of relevant information	Systematic presentation	6 Hours
Experimental data analysis from relevant literature	Systematic presentation	10 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

In order to outline the contents, the choice of teaching/learning methods, given the interest of different scientific communities (archaeology, history, history of art, etc.), the subject holder consulted the content of similar subjects taught at universities abroad.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- The ability to exemplify; - The clarity, coherence and brevity of the exposition - Correct use of calculation models, formulas and relationships; - In-depth application of knowledge	written test	70%
Tutorial	Knowing and using experimental techniques; - Interpretation of results;	oral examination	30%
Minimal requirements for passing the exam			

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Marius CĂLIN	Lect. Dr. Marius CĂLIN

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

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	Matter Structure, Atmospheric and Earth Physics, Astrophysics
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher	Conf. Dr. Cătălin Berlic						
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	DC

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	Submission of a request (Annex 1 of the Regulation on Volunteer Credits within the University of Bucharest), addressed to the Dean and submitted to the Secretariat within 30 calendar days from the beginning of the semester. The host organization must be listed in the National NGO Register (www.just.ro/registrul-national-ong) or included in the list of validated host organizations at the Faculty of Physics.
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.
Responsibility and autonomy	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

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

The content of the subject is elaborated in accordance with the content of similar subjects taught at universities in the country and abroad. The content has been harmonized with the requirements imposed by employers in the field of industry, research, university and pre-university education of all degrees.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Project	- Running the volunteer internship. - Volunteer activity recognition file		100%
Minimal requirements for passing the exam			

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. Dr. Cătălin Berlic	

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

Syllabus

Academic year 2025/2026
DFC.205 Volunteering

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher	Conf. Dr. Cătălin Berlic						
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	DC

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	Submission of a request (Annex 1 of the Regulation on Volunteer Credits within the University of Bucharest), addressed to the Dean and submitted to the Secretariat within 30 calendar days from the beginning of the semester. The host organization must be listed in the National NGO Register (www.just.ro/registrul-national-ong) or included in the list of validated host organizations at the Faculty of Physics.
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.
Responsibility and autonomy	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

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

The content of the subject is elaborated in accordance with the content of similar subjects taught at universities in the country and abroad. The content has been harmonized with the requirements imposed by employers in the field of industry, research, university and pre-university education of all degrees.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Project	- Running the volunteer internship. - Volunteer activity recognition file	The volunteer's activity report, in written format - Annex 2 of the Regulation on volunteer credits from the University of Bucharest. 50% Certificate issued by the host organization showing the number of volunteering hours completed, as well as a brief evaluation of the volunteer's activity - Annex 3 of the Regulation on volunteer credits from the University of Bucharest. 50%	100%
Minimal requirements for passing the exam	The existence of the volunteer's activity report as well as a Certificate issued by the host organization, indicating the number of volunteer hours completed and a brief evaluation of the volunteer's activity. The Volunteering Committee at the Faculty of Physics reviews the aforementioned documents and assigns the rating Accepted/Rejected.		

Date,
13.07.2025

Teacher's
name and signature,
Conf. Dr. Cătălin Berlic

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

Date of approval
15.07.2025

Head of department
name and signature
Lect. dr. Sanda VOINEA

Syllabus

Academic year 2025/2026

DFC.210 Complements of nuclear and photonuclear reactions

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Complements of nuclear and photonuclear reactions						
2.2. Teacher	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea						
2.3. Tutorials/Practicals instructor(s)	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DA

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					18
Research in library, study of electronic resources, field research					9
Preparation for practicals/tutorials/projects/reports/homework					8
Tutorat					0
Other activities					0
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	Nuclear Physics, Interaction of ionizing radiations with matter, Detection methods in Atomic and Nuclear Physics, Nuclear structure an reaction models, Quantum Physics
4.2. competences	Knowledge on nuclear models, ability in data processing and analysis and to identify and exploit available information resources.

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Multimedia room equipped with internet connection and video-projector.
5.2. for tutorials/practicals	Computing power and internet. Nuclear codes and data bases.

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology. R9. The student/graduate has in-depth knowledge of the mechanisms of nuclear fission and fusion processes, nuclear structure models, and their applications in energy and technology.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field. R9. The student/graduate is capable of analyzing and comparing different nuclear processes, using theoretical models and computational tools to evaluate nuclear reactions and energy production.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community. R9. The student/graduate can participate in projects concerning the sustainable development of nuclear energy sources, taking responsibility for evaluating the scientific, technological, and ethical impact of adopted decisions.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Review of reaction mechanisms and their modeling. Reaction mechanisms at intermediate energies. Preequilibrium models. Semi-classical approach.	Systematic exposition - lecture. Heuristic conversation. Examples	6 Hours
Exciton model. Exciton configurations. Ocuppation probabilities. Master equation. Emission rates. Particle-hole state densities. Hybrid model.	Systematic exposition - lecture. Heuristic conversation. Examples	4 Hours
Quantum preequilibrium models. Conceptual differences between quantum and semiclassical models.Multi-step direct and multi-step compound models. Monte-Carlo treatment.	Systematic exposition - lecture. Heuristic conversation.	2 Hours
Characteristics of heavy ion induced reactions. Fusion cross section calculation. Fission barrier. Moments of inertia. Level densities.	Systematic exposition - lecture. Heuristic conversation. Examples	8 Hours

References:

1. M.Herman et al, EMPIRE https://www-nds.iaea.org/empire/index.html
2. E. Gadioli and P.E. Hodgson: Preequilibrium Nuclear Reactions, Oxford University Press, 1992
3. G. Vladuca, Elemente de Fizica Nucleara, Vol.II, Ed. Universitatii din Bucuresti
4. Lecture Notes
5. recommended chapters from courses and textbooks accessible on-line

7.2 Tutorials	**Teaching techniques**	**Observations**
Calculation of preequilibrium contribution to neutron, proton, alpha and photon emission using the reaction models implemented in sevearal modules included in the EMPIRE code: PCROSS, DEGAS (exciton model), TRISTAN+ORION (multistep direct, multi-step compound), HMS (Monte Carlo)	Performing calculaions employing models, codes and data bases. Analyzing and interpreting results. Examples.	12 Hours

Calculation of cross sections and emission spectra for heavy ion induced reactions using the EMPIRE code.	Performing calculaions employing models, codes and data bases. Analyzing and interpreting results. Examples.	8 Hours

References:

1. M.Herman et al, EMPIRE https://www-nds.iaea.org/empire/index.html
2. E. Gadioli and P.E. Hodgson: Preequilibrium Nuclear Reactions, Oxford University Press, 1992
3. G. Vladuca, Elemente de Fizica Nucleara, Vol.II, Ed. Universitatii din Bucuresti
4. Lecture Notes

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

Knowledge on modeling the mechanisms of the nuclear reactions induced by different types of projectiles with low and intermediate energies is crucial for the fundamental and the applied nuclear physics. The content of this course is the result of teaching and research expertise, of the analysis of similar courses and of the interaction with research institutes and professional international organizations. It is also in line with the requirements/expectations of the potential employers of our master graduates.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- appropriate approach of the subject - coherence and clarity of exposition - correct use of equations /physical models and theories - ability to indicate/analyze specific examples	Oral examination	60%
Tutorial	Managing the models implemented in the computer codes and the input/output files to calculate reaction nuclear data.	Homeworks. Reaction data calculations.	40%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale) Correct treatment of specified subjects.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea	Prof. dr. Mihaela Sin, Conf. dr. Oana Ristea

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

Syllabus

Academic year 2025/2026
DFC.211 Current experimental problems in Atomic and Nuclear Physics

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Current experimental problems in Atomic and Nuclear Physics						
2.2. Teacher	Conf. Dr. Vasile Bercu, Lect. Dr. Marius Calin						
2.3. Tutorials/Practicals instructor(s)	Conf. Dr. Vasile Bercu, Lect. Dr. Marius Calin						
2.4 Year of study	2	2.5. Semester	2	2.6. Type of evaluation	exam	2.7.Classification	DA

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	40	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	0/20/0
Distribution of estimated time for study					
Learning by using one's own course notes, manuals, lecture notes, bibliography					18
Research in library, study of electronic resources, field research					9
Preparation for practicals/tutorials/projects/reports/homework					8
Tutorat					0
Other activities					0
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	All previous compulsory subjects with a focus on Atomic and Nuclear Physics, Particle Physics, Astrophysics
4.2. competences	General knowledge of experimental methods, relativistic nuclear physics

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Videoprojector
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R7. The student/graduate knows the operating principles and applications of specialized software for modeling atomic and nuclear processes and for analyzing experimental and simulated data. R8. The student/graduate knows advanced concepts in nuclear physics, elementary particles, astrophysics, and cosmology.
Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R7. The student/graduate uses computing codes or software packages for research topics and specific applications. R8. The student/graduate uses modern methods of analysis and numerical simulation, integrating efficiently in international teams and contributing to frontier research in the field.

Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R7. The student/graduate demonstrates autonomy in using and developing computing programs, taking responsibility for respecting licensing norms and collaborative practices typical of open-source code development. R8. The student/graduate participates actively and responsibly in international projects, respecting the scientific, ethical, and collaborative standards of the fundamental physics research community.

7. Contents

7.1 Lecture [chapters]	**Teaching techniques**	**Observations**
Detection of molecular species - Interaction of atoms and molecules with the surface	Systematic exposition - lecture. Examples	4 Hours
Interaction potentials, surface models.	Systematic exposition - lecture. Examples	3 Hours
Processes of physisorption, chemisorption, migration on the surface	Systematic exposition - lecture. Examples	3 Hours
Detectors with new sensitive volumes	Systematic exposition - lecture. Examples	4 Hours
Detectors with extremely large sensitive volumes for Astrophysics	Systematic exposition - lecture. Examples	3 Hours
The need for complex detection systems	Systematic exposition - lecture. Examples	3 Hours

References:

1. Andrew Zangwill, Physics at Surfaces, Cambridge 1988
2. Molecular Physics Laboratory, the team of the Atomic and Nuclear Physics department
3. M.-C. Desjonquères si D. Spanjaard , Concepte de fizica suprafetei, Editura Tehnica 1998
4. G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000
5. W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003).
6. Claus Grupen, Astroparticle Physics, Springer-Verlag Berlin Heidelberg 2005
7. L. Pandola, Overview of the European Underground Facilities, arXiv:1102.020

7.3 Practicals	**Teaching techniques**	**Observations**
Detection of molecular species, gas detectors	Practical activity	2 Hours
Calculation of surface atom interaction potentials	Practical activity	2 Hours
Surface atom collisions - simulations by molecular dynamics	Practical activity	3 Hours
Energy distribution at the basal planes of graphite in inelastic collisions with xenon atoms	Practical activity	3 Hours
Simulations for detectors		10 Hours

References:

1. Andrew Zangwill, Physics at Surfaces, Cambridge 1988
2. Molecular Physics Laboratory, the team of the Atomic and Nuclear Physics department
3. M.-C. Desjonquères si D. Spanjaard , Concepte de fizica suprafetei, Editura Tehnica 1998
4. G.F. Knoll, Radiation Detection and Measurement, Wiley, 2000
5. W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, (Springer-Verlag, Berlin, 1987 and 2003).
6. Claus Grupen, Astroparticle Physics, Springer-Verlag Berlin Heidelberg 2005
7. L. Pandola, Overview of the European Underground Facilities, arXiv:1102.020

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

In order to establish the content of the course and the laboratory, the choice of teaching/learning methods, the analytical programs of similar subjects taught at universities in the country and abroad were consulted. The subject content is in accordance with the requirements for employment as a physicist in physics research institutes and in education (under the law).

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	Knowledge of theoretical notions	Written exam and oral assessment	50%
Tutorial			50%
Minimal requirements for passing the exam	Requirements for mark 5 (10 points scale) Completion of all laboratory work and grade 5 in the laboratory colloquium The correct exposure of the indicated subjects to obtain a score of 5 in the final exam.		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. Dr. Vasile Bercu, Lect. Dr. Marius Calin	Conf. Dr. Vasile Bercu, Lect. Dr. Marius Calin

Date of approval

15.07.2025

Head of department
name and signature
Lect. dr. Sanda VOINEA

Syllabus

Academic year 2025/2026
DFC.212 Nuclear security

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	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Nuclear security
2.2. Teacher	Lect. Dr. Marius CĂLIN, CS III Andrei APOSTOL
2.3. Tutorials/Practicals instructor(s)	CS III Andrei APOSTOL, drd. Alexandru BEREVOIANU

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

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	40	3.5. Lectures	20	3.6. Tutorials/Practicals/Projects	0/20/0

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	Atomic Physics, Nuclear Physics, Optics, Quantum Physics, Statistical Physics
4.2. competences	Programming languages, Processing of physical data and numerical methods

5. Conditions/Infrastructure (if necessary)

5.1. for lecture	Lecture hall (preferred, but not mandatory, multimedia equipment)
5.2. for tutorials/practicals	Experimental modules from the Nuclear Forensics Laboratory (NIPNE-RO) and particle accelerators in NIPNE-HH, computer network (or individual laptops)

6. Learning outcomes

Knowledge	R1. The student/graduate deeply understands the principles of atomic and nuclear physics, including theoretical models, methods, and experimental techniques. R2. The student/graduate knows the mechanisms of radiation interaction with matter, the operating principles of the main classes of detectors, and their applications in technological and medical fields. R3. The student/graduate knows and understands the operating principles and applicability of fundamental equipment used in each subfield of atomic and nuclear physics. R4. The student/graduate knows the fundamental concepts of dosimetry as well as the principles and rules of radiological protection. R5. The student/graduate has advanced knowledge of the behavior of radionuclides in the environment, as well as of the natural and anthropogenic processes that influence environmental radioactivity. R10. The student/graduate should know the norms and ethical principles regarding scientific research in the field, as well as develop a culture of responsibility in intellectual work.

Skills	R1. The student/graduate applies theoretical concepts in various related fields (nuclear energy, high-energy physics, cosmology and astrophysics, nuclear medicine, radiation protection, and radiological hygiene). R2. The student/graduate uses radiation detection and measurement systems, adapted to various applications (medical, industrial, and fundamental research). R3. The student/graduate collects and interprets data obtained through scientific methods, integrating the results within an analytical framework. R4. The student/graduate applies and evaluates safety and radiological protection regulations, applicable in educational and research laboratories. R5. The student/graduate uses sampling, analysis, and data interpretation methods for radioactive contamination, including spectrometry and dosimetry techniques applied in environmental contexts. R10. The student/graduate should assimilate explicit norms (normative texts) or implicit ones (customs, practices) that regulate academic and research conduct in the field.
Responsibility and autonomy	R1. The student/graduate plans and manages complex projects in atomic and nuclear physics, acting autonomously and responsibly in decision-making. R2. The student/graduate efficiently organizes professional activities and working time in accordance with the pursued objectives. R3. The student/graduate analyzes experimental data and extracts relevant information about the quantities of interest. R4. The student/graduate takes responsibility for complying with radiological protection norms and ethical standards in multidisciplinary teams. R5. The student/graduate complies with safety and radiation protection regulations, taking responsibility for risk assessment and the protection of the environment and public health. R10. The student/graduate should demonstrate solidarity, responsiveness, and support for strengthening academic integrity.

7. Contents

7.1 Lecture [chapters]	Teaching techniques	Observations
Introductory notions of nuclear physics: types of radioactive decays, the law of radioactive decay, half-life, isotopes, isobars	Systematic exposition - lecture. Examples	2 Hours
Principles of radiation protection and notions of dosimetry. Types of ionizing radiations. Notions of nuclear electronics. Types of detectors used in the detection and measurement of ionizing radiations	Systematic exposition - lecture. Examples	2 Hours
Introduction to Nuclear Security: historical evolution and contemporary relevance. Overview of nuclear security threats. National legislation and international conventions on nuclear security	Systematic exposition - lecture. Examples	2 Hours
Nuclear materials and radioactive sources. Ionizing radiation detection, alarm adjudication and crime scene security. Investigations at the scene of the radiological crime. Roles and responsibilities. Personal protective equipment and techniques for the detection, identification and analysis of radioactive materials	Systematic exposition - lecture. Examples	2 Hours
Nuclear Forensics: categorization and characterization of radioactive materials	Systematic exposition - lecture. Examples	2 Hours
Forensic techniques applied to material means of evidence contaminated with radionuclides	Systematic exposition - lecture. Examples	2 Hours
Nuclear Forensic Signatures, Data Analysis and Interpretation Methods	Systematic exposition - lecture. Examples	2 Hours

Interface between Nuclear Security, Nuclear Safety and Nuclear Safeguards. International cooperation in the field of nuclear safety and security: IAEA, ITWG, GICNT, UNODC, UNOCT, UNICRI, JRC EC.	Systematic exposition - lecture. Examples	2 Hours
Case Studies on Nuclear Security Events	Systematic exposition - lecture. Examples	2 Hours
Nuclear security in the context of SMR deployment	Systematic exposition - lecture. Examples	2 Hours

References:

1) Nuclear Security Series, IAEA, https://www.iaea.org/resources/nuclear-security-series
2) K.J. Moody, P.M. Grant, I.D. Hutcheon, Nuclear Forensic Analysis, CRC Press, Taylor and Francis Group, Boca Raton, FL, Print ISBN:978-0-8493-1513-8. eBook ISBN:978-0- 203-50780-3 (2005)
3) Gordon R. Gilmore, Practical Gamma-ray Spectrometry – 2nd Edition, John Wiley and Sons, Ltd. ISBN: 978-0-470-86196-7 (2008).
4) IAEA-TECDOC-2019, Establishing a Nuclear Forensic Capability: Application of Analytical Techniques, https://www-pub.iaea.org/MTCD/publications/PDF/TE-2019web.pdf

7.3 Practicals	**Teaching techniques**	**Observations**
High-resolution gamma spectrometry. Commissioning of a spectrometric detection chain, energy calibration and determination of the absolute efficiency curve. Calculation programs relevant to the analysis of nuclear materials and radioactive sources	Guided practical work	4 Hours
Dosimeter measurements: Equipment used, legal considerations, dose limits and protective equipment		4 Hours
Identification of radioactive isotopes (gamma spectrometry measurements on nuclear materials or other radioactive materials). Determination of the isotopic composition of uranium and plutonium and identification of their age: by gamma spectrometry, calculation programs and manual calculation.		4 Hours
Forensic techniques: X-ray fluorescence, papillary traces, optical microscopy and scanning electron microscopy		4 Hours
On-site investigations of radiological crime: Personal protective equipment, detection equipment, legal considerations.		4 Hours

References:

1) Training on measurements in nuclear forensics: Gamma spectrometry, laboratory documents developed by NIPNE-HH within the joint course with the Los Alamos National Laboratory, USA.
2) International Atomic Energy Agency (IAEA) Courses, Radiological Crime Scene Investigations
3) Gordon R. Gilmore, Practical Gamma-ray Spectrometry – 2nd Edition, John Wiley and Sons, Ltd. ISBN: 978-0-470-86196-7 (2008).

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

In order to outline the contents, the choice of teaching/learning methods, given the special importance of the discipline for applications in physics and modern technology, the holders of the discipline consulted the content of similar disciplines taught at universities in the country and abroad.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Lecture	- Clarity, coherence and conciseness of presentation; - Correct use of calculation models, formulas and relationships; - The ability to exemplify; - In-depth application of knowledge	Written exam	70%

Practical	- Knowledge and use of experimental techniques; - Interpretation of the results;	Laboratory colloquim	30%
Minimal requirements for passing the exam	• Performing all practical activities during the semester • Obtaining grade 5 by adding up the points obtained for the activities during the course and the exam, in accordance with the specified weight		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Lect. Dr. Marius CĂLIN, CS III Andrei APOSTOL	CS III Andrei APOSTOL, drd. Alexandru BEREVOIANU

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

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	Matter Structure, Atmospheric and Earth Physics, Astrophysics
1.4. Field of study	Fizică/Physics
1.5. Course of study	Master
1.6. Study program	Physics of Atom, Nucleus, Elementary Particles, Astrophysics ans Applications

2. Course unit

2.1. Course unit title	Volunteering						
2.2. Teacher	Conf. Dr. Cătălin Berlic						
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	DC

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	Submission of a request (Annex 1 of the Regulation on Volunteer Credits within the University of Bucharest), addressed to the Dean and submitted to the Secretariat within 30 calendar days from the beginning of the semester. The host organization must be listed in the National NGO Register (www.just.ro/registrul-national-ong) or included in the list of validated host organizations at the Faculty of Physics.
5.2. for tutorials/practicals	

6. Learning outcomes

Knowledge	R11. The student/graduate should know the principles of communication and collaboration in multidisciplinary teams and the hierarchical structure specific to organizations.
Skills	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.
Responsibility and autonomy	R11. The student/graduate should apply effective communication and coordination techniques in diverse teams, managing tasks and professional relationships at various hierarchical levels.

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

The content of the subject is elaborated in accordance with the content of similar subjects taught at universities in the country and abroad. The content has been harmonized with the requirements imposed by employers in the field of industry, research, university and pre-university education of all degrees.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Weight în final mark
Project	- Running the volunteer internship. - Volunteer activity recognition file		100%
Minimal requirements for passing the exam	Obţinerea notei 5 - Promovarea colocviului de laborator - Obtinerea notei 5 prin însumarea punctelor obţinute la activităţile de pe parcurs şi examen, în acord cu ponderile specificate Obţinerea notei 10 - Capacitate demonstrată de analiză a fenomenelor şi proceselor - Rezolvarea corectă si argumentata a tuturor subiectelor		

Date,	Teacher's name and signature,	Practicals/Tutorials/Project instructor(s), name and signature
13.07.2025	Conf. Dr. Cătălin Berlic	

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