DI.101.HEP Relativistic quantum mechanics and Quantum electrodynamics

1. Study program

1.1. University	University of Bucharest, "Alexandru Ioan Cuza" University of Iaşi, "Babeş-Bolyai" University of Cluj-Napoca,
1.2. Faculty	Faculty of Physics
1.3. Department	Department of Theoretical Physics, Mathematics, Optics, Plasma and Lasers
1.4. Field of study	Physics
1.5. Course of study	Master of Science
1.6. Study program	High Energy Physics (in English)
1.7. Study mode	Full-time study

2. Course unit

2.1. Course unit title	***Relativistic quantum mechanics and Quantum electrodynamics***							
2.2. Teacher				Prof. dr. DARIESCU Marina-Aura, Lect.dr. LAZAR Zsolt				
2.3. Tutorials/Practicals instructor(s)				Prof. dr. DARIESCU Marina-Aura, Lect.dr. LAZAR Zsolt				
2.4. Year of study	I	2.5. Semester	1	2.6. Type of evaluation	E	2.7. Type of course unit	Content[1)]	**DS**
							Type[2)]	**DI**

[1)] fundamental (DF), specialized (DS); complementary (DC)
[2)] compulsory (DI), elective (DO), noncompulsory disciplines (DFC)

3. Total estimated time (hours/semester)

3.1. Hours per week in curriculum	**4**	distribution: Lecture	**2**	Practicals/Tutorials	**2**
3.2. Total hours per semester	**56**	Lecture	**28**	Practicals/Tutorials	**29**
Distribution of estimated time for study					**hours**
3.2.1. Learning by using one's own course notes, manuals, lecture notes, bibliography					**30**
3.2.2. Research in library, study of electronic resources, field research					**30**
3.2.3. Preparation for practicals/tutorials/projects/reports/homeworks					**30**
3.2.4. Examination					**4**
3.2.5. Other activities					**0**

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

4. Prerequisites (if necessary)

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

5. Conditions/Infrastructure (if necessary)

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

6. Specific competences acquired

Professional competences	Identify and proper use of the main physical laws and principles in a given context; Identify and proper use of the main physical laws and principles of relativistic quantum mechanics and electrodynamics. Using in a creative way of the knowledge acquired in modeling of processes in relativistic quantum mechanics and electrodynamics. Disemination and analyzing of the scientific information in physics Using and development of specific software tools for numerical and analytical calculations in QED processes
Transversal competences	Efficient use of sources of information and communication resources and training assistance in a foreign language. Carrying out professional tasks in an efficient and responsible manner, in compliance with the specific legislation, ethics and deontology.

7. Course objectives

7.1. General objective	-Understanding the fundamental aspects related to the study of quantum mechanics. Training capacities to approach and solve specific problems. Developing analytics skills of calculation.
7.2. Specific objectives	- Understanding the formalism of relativistic quantum mechanics and of quantum electrodynamics - Understanding the properties of Dirac equation solutions - Understanding the physical implications of the mathematical properties of Dirac equation solutions (spin, the positron existence) - Understanding of the quantization methods - Description of some fundamental processes în quantum electrodynamics - Developing the capability to analyse and compare diverse phenomena, starting from basic principles - Obtaining a good theoretical understanding of the studied problems - Developing the capability to use the theoretical knowledge to describe some physical systems

8. Contents

8.1. Lecture [chapters]	Teaching techniques	Observations/ hours
Time-dependent Perturbation Theory: Heisenberg and Schrodinger pictures, Transition amplitudes and probability, the S-matrix formalism.	Systematic exposition - lecture. Examples	4 hours (online)
Summary of Special Relativity: Lorentz transformations, Four-vectors, tensors, Maxwell’s equations in Lorentz covariant from Discrete transformations (spatial and temporal inversion)	Systematic exposition - lecture. Examples	4 hours (online)
Relativistic bosons: The Klein-Gordon Equation.	Systematic exposition - lecture. Examples	4 hours (online)
Covariant form of the Dirac equation, Properties of the gamma matrices The “Weyl” representation and the neutrino	Systematic exposition - lecture. Examples	4 hours (online)

Free Particle Solutions to the Dirac Equation		
Interactions of a Relativistic Electron with an External Electromagnetic Field	Systematic exposition - lecture. Examples	4 hours (online)
QED as a Gauge Theory	Systematic exposition - lecture. Examples	4 hours (online)
Basics of Quantum Field Theories: annihilation-creation algebra, The S matrix. Wick theorem, Feynman diagrams	Systematic exposition - lecture. Examples	4 hours (online)

Bibliography:
F. Schwabl, Advanced Quantum Mechanics, Springer Verlag, 2005.
W. Greiner, Relativistic Quantum Mechanics, Springer Verlag , 2000
A. Wachter, Relativistic Quantum Mechanics, Springer, 2011
F. Mandl, G. Shaw, Quantum Field Theory, John Wiley&Sons, 2010
M. Peskin, D. Schroeder, An Introduction to Quantum Field Theory, Addison Wesley, 1996
W. Greiner, J. Reinhardt, Quantum Electrodynamics, Springer,2009
C. Itzykson, J.-B. Zuber, Quantum Field Theory, McGraw-Hill, 1980
A.I. Akhiezer, V.B. Berestetskii, Quantum Electrodynamics, Interscience, 1965

8.2. Tutorials [main themes]	Teaching and learning techniques	Observations/hours
Time-dependent Perturbation Theory: Applications. Transition amplitudes and probability, Absorption and stimulated emission.	Lecture. Problem solving.	4 hours (online)
The Klein-Gordon equation. Applications.	Lecture. Problem solving.	4 hours (online)
Interactions of a Relativistic scalar with an External Electromagnetic Field	Lecture. Problem solving.	4 hours (online)
Properties of the Dirac matrices, Representations, calculation of the traces.	Lecture. Problem solving.	4 hours (online)
The Dirac Equation. Applications.	Lecture. Problem solving.	4 hours (online)
The Feynman propagator for the Klein Gordon and Dirac equations	Lecture. Problem solving.	4 hours (online)
Calculation of cross section for some fundamental processes	Lecture. Problem solving.	4 hours (online)

Bibliography:
1. B. Thaller , The Dirac Equation, Springer Verlag, 1992
2. W. Greiner, Relativistic Quantum Mechanics, Springer Verlag , 2000
3. W. Greiner, J. Reinhardt, Quantum Electrodynamics, Springer,2009

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

The contents and teaching methods were selected after a thorough analysis of the contents of similar course units in the syllabus of other universities from Romania or the European Union. The contents are in line with the requirements/expectations of the main employers of the graduates (industry, research, academic, secondary school teaching).

10. Assessment

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

			Weight in final mark
10.4. Lecture	- coherence and clarity of exposition - correct use of equations/mathematical methods/physical models and theories - ability to indicate/analyse specific examples	Written test/oral examination	60%
10.5.1. Tutorials	- ability to use specific problem solving methods	Homeworks/written tests	40%
10.6. Minimal requirements for passing the exam **Requirements for mark 5** Attendance of at least 50% for the lectures and at least 70% for the tutorials. Correct solutions to the indicated subjects for obtaining the grade 5 from all activities, part of the continuous evaluation. Correct solutions to the indicated subjects for obtaining the grade 5 within the final ex **Requirements for mark 10** Attendance of at least 50% for the lectures and at least 70% for the tutorials. Correct solutions to the all the subjects at the final exam and the continuous evaluation			

Date 16.09.2024

Teacher’s name and signature
Prof. dr. DARIESCU Marina-Aura, Lect.dr. LAZAR Zsolt

Tutorials instructor name and signature
Prof. dr. DARIESCU Marina-Aura, Lect.dr. LAZAR Zsolt

Date of approval

Head of Department
Lect. Dr. Roxana Zus