Anexa Nr. 2

Subject content

1. Program information

1.1. University	West University of Timișoara
1.2. Faculty	Physics
1.3. Departament	Physics
1.4. Study direction	Physics
1.5. Study cycle	Master
1.6. Study program*	**Advanced Research Methods in Physics** / conform COR: fizician (211101); profesor în învăţământul gimnazial (232201 - în condiţiile legii); asistent de cercetare (248102); referent de specialitate în învăţământ (235204); analist (213101; analist financiar (241493).

2. Subject matter information

2.1. Subject matter			Symmetries in physics				
2.2. Subject teacher			Victor E. AMBRUȘ				
2.3. Subject applications teacher			Victor E. AMBRUȘ				
2.4. Study year	I	2.5. Semester	I	2.6. Assesment type	**E**	2.7. Subject type	**DOP - ARMP 1105**

3. Study time distribution

3.1. Nr. of hours / week	4	In which: 3.2 course	2	3.3. Problem class	2
3.4. Total hours in educational plan	56	In which: 3.5 course	28	3.6. Problem class	28

Time distribution*	**hrs**
Study after lecture notes, bibliography or notes	52
Additional documentation in the library, electronic specialty platforms/ field	26
Seminar/ laboratory preparations, homework, portfolio and essays	26
Tutoring	7
Exams	8
Other activities....	

3.7. Total number of personal study hours	119
3.8. Total number of hours in semester	175
3.9. Number of credits	7

4. Preconditions

4.1. Curriculum	• Fizica atomului și moleculei (FF2301); • Mecanică cuantică (FF2401); • Electrodinamică (FF2402); • Fizica particulelor elementare (FF3602);
4.2. Skills	• General skills: ability to assimilate fundamental knowledge; correct usage of physics-specific terminology; ability to work individually and as part of a team; • Professional skills: the correct identification and usage of the main laws and principles of physics; ability to solve physics-specific problems.

5. Conditions (where applicable)

5.1 for course implementation	•
5.2 for seminar/laboratory implementation	•

6. Course objectives – expected results achieved by attending and graduating this course

Knowledge	• Basic notions of group theory with applications in physics • To offer a unified view on physical theories using symmetry principles • Role of rotations, Lorentz and Poincare groups in characterizing states in relativistic quantum mechanics • SU(3) group as isospin symmetry group, as well as colour gauge group
Abilities	• Solving problems in quantum and elementary particle physics using group theoretical methods • Using Young Tableaux to identify the irreducible representations of the direct (Kronecker) product of SU(N) states
Responsability and autonomy	• Acquaintance with group theory and its applications in physics • Understanding the properties of elementary particles based on the Poincare symmetry group • Understanding the properties of special unitary (SU) groups as gauge groups

7. Table of contents

7.1. Course	Teaching methods	Observations
Chap.1. Discrete symmetry groups (6 hours) • Basic notions of abstract group theory • Group representations • Representations of the symmetric group; Young diagrams	Interactive lecturing at the blackboard or using the beamer.	[1] Chaps. 2, 3, 5; [2] Chaps. 1, 2, 3; [3] Chap. 11. [6] Chaps. 1, 21-24
Chap.2. Continuous symmetry groups (6 hours) • Lie groups • The rotation group and the group SU(2) • The translation and rotation groups in quantum mechanics		[1] Chaps. 7,8, 9; [2] Chaps. 6, 8; [3] Chap. 4; [8] Chap. 5.
Chap. 3. The Lorentz and Poincare groups (10 hours) • The Lorentz and Poincare groups • Unitary representations of the Poincare group • Discrete symmetries; Representations of the full Poincare group • Symmetries and conserved quantities		[1] Chaps. 10, 11; [2] Chap. 10.4; [3] Chaps. 3.3, 7.2; [5] Chap. 4.

Chap. 4. Special unitary groups (6 hours) • The group SU(3); Young diagrams; Roots and weight vectors • Quarks and the eight-fold way • Gauge theories of elementary particles		[2] Chap. 8; [3] Chap. 5.2; [6] Chaps. 7, 11; [7] Chaps. 2.2, 2.3, 3, 4

Bibliography

1. Wu-Ki Tung, Group theory in physics (World Scientific, 1985)
2. H. Jones, Groups, representations and physics (Adam Hilger, 1990)
3. A. Zee, Group theory in a nutshell for physicists (Princeton University Press, 2016)
4. R. Gilmore, Lie group, physics and geometry (Cambridge, 2008)
5. J. Schwichtenberg, Physics from symmetry (Springer, 2015)
6. H. Georgi, Lie algebras in particle physics (Westview Pres, 1999)
7. K. Huang, Quarks, leptons and gauge fields (World Scientific, 1992)
8. T. Frankel, The Geometry of Physics (Cambridge, 2004)

7.2. Seminar/laboratory	Teaching methods	Observations
Chap.1. Discrete symmetry groups (6 hours) • Representations of simple finite groups • Decompositions of representations • Splitting of energy levels and selection rules • Tensorial operators • Wigner-Eckart theorem and applications	Problem solving at the blackboard and in the notebooks.	The bibliographic references follow those from the course.
Chap.2. Continuous symmetry groups (6 hours) • Representations of SU(2) • The hidden SO(4) symmetry of the hydrogen atom • Thomas precession and the spin-orbit coupling		
Chap. 3. The Lorentz and Poincare groups (10 hours) • Representations of the Lorentz group and fundamental fields • Conserved operators in relativistic field theories		
Chap. 4. Special unitary groups (6 hours) • Decomposition of representations of the gropup SU(3) • Isospin symmetry: baryon octet and decouplet • Mass fomulas and relations between scattering amplitudes • Gauge models		

Bibliography

See 7.1. Course.

8. Matching course contents with expectations of representatives of the academic community, of professional associations and of representative employers of the study programme domain

Knowing and understanding the specific techniques studied in this course, formation and development of practical abilities to correctly and completely interpret results, practice of the teamwork spirit and of the ability to organise and investigate, nurturing a scientific environment based on values, professional ethics

and quality. The course covers basic aspects of group theory and its applications in physics, with an emphasis on the rotation, translation and Poincare groups, as well as the SU(N) special unitary groups. Graduates will be able to identify the irreducible and reducible representations of the symmetry groups, as well as the physical contents of quantum states. Understanding the approximate isospin symmetry will allow graduates to have a better grasp on the classification of the hadronic states observed in high-energy collider experiments.

9. Assessment

Activity type	Assessment criteria	Assessment methods	Percent în final mark
9.1. Course	For 50% marks: fundamental notions from this field. For 100% marks: advanced notions from this field.	1. Written evaluation: questions with multiple-choice answers. 2. Oral examination: a) elementary topics; b) advanced topics.	**34%+33%**
9.2 Seminar/laboratory	For 50% marks: fundamental notions from this domain. For 100% marks: advanced notions from this domain.	3. Written evaluation: Problem solving.	**33%**
10.6. Minimum performance standards			
• 50% marks for multiple-choice answer test; • 50% marks for problem test; • Oral examination on elementary topics. Alternatively: • 50% marks for multiple-choice answer test; • Written project on one of the course themes.			

- Minimum attendance: according to the applicable WUT regulations (course 50%; seminar 70%).
- Final mark: 34% multiple-choice test, 33% written exam, 33% oral examination. Bonus points awarded for good attendance and for timely homework submission.

Date of filing: Signature of Course leader:

16.09.2024 Lect. Univ. Dr. Victor E. AMBRUȘ

Date of departmental approval: Signature of Head of Department:

_____ Conf. Univ. Dr. Nicoleta ȘTEFU