

Advanced Mathematical Methods

Code: 100167
ECTS Credits: 5

2024/2025

Degree	Type	Year
2500097 Physics	OT	3

Contact

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Teachers

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Teaching groups languages

You can view this information at the [end](#) of this document.

Prerequisites

It is advisable to have studied the following subjects:

Calculus in one variable
Vector Calculus
Differential equations

Objectives and Contextualisation

This subject introduces some basic mathematical concepts
needed in physics in general, and in physics / Quantum mechanics

and field theories, in particular. It is intended that the student
achieve the understanding of the concepts of Hilbert space, operators, di

and, especially, groups. It wants to give an integrative vision
of concepts that appear in different fields in physics. At the same time,

the student will have to acquire the capacity to apply them with agility for different types of problems.

Competences

- Act with ethical responsibility and respect for fundamental rights and duties, diversity and democratic values.
- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Develop the capacity for analysis and synthesis that allows the acquisition of knowledge and skills in different fields of physics, and apply to these fields the skills inherent within the degree of physics, contributing innovative and competitive proposals.
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project

Learning Outcomes

1. Classify representations of the most simple groups.
2. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
3. Determine the effect on the observables of symmetry transformation.
4. Determine the observables that characterise representation.
5. Determine the representation that characterizes a particular physical system.
6. Determine the symmetry group (exact or approximate) associated with a physical system.
7. Explain the explicit or implicit code of practice of one's own area of knowledge.
8. Identify situations in which a change or improvement is needed.
9. Identify symmetry groups associated with the laws of physics.
10. Identify symmetry groups associated with theories of fundamental interactions.
11. Identify symmetry groups in addition to their particle and crystallography representations, associated with atomic physics.
12. Identify the social, economic and environmental implications of academic and professional activities within one's own area of knowledge.
13. Obtain representation of simple symmetry groups.
14. Relate continuous groups with the Lie algebra to which they are associated.
15. Relate the symmetries of nature with the appropriate symmetry group (exact or approximate).
16. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
17. Use the tensor calculus.
18. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.

Content

PROGRAM

1. Hilbert spaces

1.1 Pre-Hilbert spaces.

2.2 Hilbert spaces.

2. Operators.

2.1 Linear operators.

2.2 Eigenvalues and eigenvectors.

3. Distributions

4. Introduction to group theory

4.1 Definition and motivation (symmetries)

4.2 Examples: $SO(3)$, $SU(2)$, $SU(N)$ (relation with unitary operators).

4.3 Lie algebras (generators of the continuous group)

4.4 $su(N)$ (relation with selfadjoint operators) and relation with $su(2)$ with $so(3)$

5. Representations

6. Tensorial methods

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Blackboard lectures: the professor will expone basic concepts and arguments for each subject, with the support of detailed examples.	27	1.08	
Practical lectures: among a problems collection, the professor will solve a set of them. The rest will be solved by the students.	14	0.56	
Type: Autonomous			
Individual and groupal work solving problems	28	1.12	
Selective homework	11	0.44	
Study of teoretical foundations	37	1.48	

This course develops mathematical language and calculation tools that are basic for advanced physics subjects. The personal work of the student is fundamental. Classroom sessions will be divided into:
 Lectures: The teacher will present the basic concepts and reasoning of the Subject, with the support of examples.
 Problem classes: Among a collection of problems, the teacher will solve in detail a selection. Students will have to work on their own the

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Final exam	50%	2.5	0.1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Homework	5%	0.25	0.01	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Make-up exam	95%	3	0.12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
Midterm exam	45%	2.25	0.09	2, 7, 8, 12, 16, 17, 18

Grading (Ordinary)

A) Mid-Term exam (45% of the grade): written exam, without books, individual, about mid semester.

B) Final Exam (50 % of the grade): written exam, without books, individual, at the end of the semester.

C) Take-home exercises (5% of the grade): There will be several exercises to be handed in about the end of the semester.

The final grade will be the result of A+B+C.

D) Make-up exam (95% of the grade): If the grade achieved in A+B $> 3.5/10$, the student will have the right to take a final make-up exam provided he/she has already taken the exams A+B. The grade achieved in this exam will replace the grade achieved in the exams A+B in all cases.

Grading ("Avaluacio Unica")

A) Final exam (45 % of the grade): written exam, without books, individual, at the end of the semester.

B) Oral exam (55 % of the grade) : individual exam, at the end of the semester.

C) Final oral make-up exam (100 % of the grade): oral exam, optional, at the end of the semester. If the grade achieved in A+B $> 3.5/10$, the student will have the right to take a final make-up exam provided he/she has already taken the exams A+B. The grade achieved in this exam will replace the grade achieved in the exams A+B in all cases.

Both gradings (ordinary and "avaluacio unica") will have the final exam on the same day. Idem for the make-up exams.

Bibliography

Basic bibliography.

P. Szekeres, *A course in Modern Mathematical Physics*.

Elvira Romera et al., Métodos matemáticos: Problemas de espacios de Hilbert, operadores lineales y espectros

G. Arfken, *Mathematical Methods for Physics*.

Advanced and complementary bibliography.

J.J. Sakurai, *Modern Quantum Mechanics*.

J.F. Cornwell, *Group theory in Physics*.

H. Georgi, *Lie Algebras in particle physics*.

L. Abellanas i A. Galindo, *Espais de Hilbert*.

S.K. Barbarian, *Introducció a l'espai de Hilbert*.

L. Schwartz, *Métodos Matemáticos para las ciencias físicas*.

Software

Not conceived.

Language list

Name	Group	Language	Semester	Turn
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(PAUL) Classroom practices	1	English	first semester	morning-mixed
(TE) Theory	1	English	first semester	morning-mixed