

In view of the health context linked to the spread of the coronavirus, the methods of organisation and evaluation of the learning units could be adapted in different situations; these possible new methods have been - or will be - communicated by the teachers to the students.

5 credits

22.5 h + 22.5 h

Q2

Teacher(s)	Ruelle Philippe ;
Language :	English
Place of the course	Louvain-la-Neuve
Main themes	This course is a general introduction to group theory, with a strong orientation towards its use in Physics. Symmetries are fundamental in Physics and are mathematically formalized by the concept of group. Therefore physicists need to know how to formulate a symmetry, how to use it and understand all the consequences of it. In this regard, the notion of representation is central, as it encapsulates the way physical quantities behave under the symmetry transformations. After a brief review of some general aspects of groups, the course will focus on the study and use of their representations. A few concrete applications will show the efficiency of group methods in Physics.
Aims	<p>a. Contribution of the teaching unit to the learning outcomes of the programme (PHYS2M and PHS2M1) 1.1, 1.5, 2.1, 2.3, 3.1, 3.2, 3.3, 3.4.</p> <p>b. Specific learning outcomes of the teaching unit At the end of the teaching unit, the student will be able to :</p> <ol style="list-style-type: none"> 1. formulate a symmetry in terms of a group; 2. analyze the consequences of a symmetry by the use of representations of the associated group ; 3. understand the importance of group representations in Physics ; 4. calculate characters of representations ; 5. identify different types of representations ; 6. calculate the reduction of a representation of a finite group in irreducible representations, and identify the associated invariant subspaces ; 7. calculate the algebra of a matrix group and determine its dimension ; 8. characterize a representation of $su(2)$; 9. calculate $su(2)$ Clebsch-Gordan coefficients. <p>----- The contribution of this Teaching Unit to the development and command of the skills and learning outcomes of the programme(s) can be accessed at the end of this sheet, in the section entitled "Programmes/courses offering this Teaching Unit".</p>
Evaluation methods	<p>Due to the COVID-19 crisis, the information in this section is particularly likely to change. The evaluation is based on a written exam, with the objective to test the knowledge, the understanding and the use in simple and concrete problems, of the mathematical notions and techniques developed in the course. Emphasis will be put on the capacity to analyze a new but simple situation, rather than on the proof of mathematical and abstract results.</p>
Teaching methods	<p>Due to the COVID-19 crisis, the information in this section is particularly likely to change. The teaching consists of lectures and tutorials.</p> <p>The lectures aim at introducing the fundamental concepts of group theory which are central to understand its role in physics. In particular certain concepts developed in other courses of the undergraduate physics program are revisited from a purely group theoretic point of view, thereby showing the full relevance of group methods. The most useful results of group theory are presented and the associated methods are made completely explicit.</p> <p>The tutorials are meant to get familiar with the theoretical material and the methods presented during the lectures. Attendance to both the lectures and the tutorials is required.</p>
Content	<p>The course consists of two main parts, whose content is detailed hereafter. Depending on the time availability, the material marked with a star, somewhat more advanced, might not be discussed.</p> <p>1. Finite groups :</p> <ul style="list-style-type: none"> ' basic notions, properties and examples (invariant subgroup, direct and semi-direct product, conjugacy classes, left and right cosets, quotient group, illustrations in symmetric groups) ; ' concept of representation (motivations, definitions, examples, equivalence classes of representations, direct sums, distinction between reducible and irreducible, classification problem) ;

	<p>' general results for finite groups (characters, orthogonality relations, irreducible character tables, reduction methods, applications) ;</p> <p>' tensor product of representations (definition, reduction of tensor products, practical efficiency of tensorial notation, examples) ;</p> <p>' mathematical characterization and consequences of symmetries in a concrete physical system (calculation of the normal modes of a mechanical system from the identification of irreducible representations in the symmetry group action) ;</p> <p>' (*) symmetric groups (irreducible representations associated to Young diagrams, dimensions, characters).</p> <p>2. Lie groups and Lie algebras :</p> <p>' the group $SO(2)$ (defining representation, infinitesimal generators) ;</p> <p>' generalization to matrix groups (Lie algebra, exponential map, structure constants, representation of the algebra, group composition law) ;</p> <p>' the groups $SU(2)$ and $SO(3)$ (group varieties, parametrizations, relation between the two) ;</p> <p>' the $su(2)$ algebra (irreducible representations, reduction of tensor products, Clebsch-Gordan coefficients) ;</p> <p>' (*) representations of the $su(3)$ algebra (examples, general structure and classification, reduction of tensor products, applications to the quantum harmonic oscillator) ;</p> <p>' (*) representations of classical matrix groups (tensorial methods, role of permutation groups, Young diagrams and dimension formulas, peculiarities of the orthogonal groups, application to the Riemann tensor).</p>
<p>Inline resources</p>	<p>The lecture notes are available on the MoodleUCL website of the teaching unit.</p>
<p>Bibliography</p>	<p>Syllabus disponible sur MoodleUCL.</p>
<p>Faculty or entity in charge</p>	<p>PHYS</p>

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Aims
Master [60] in Physics	PHYS2M1	5		
Master [120] in Physics	PHYS2M	5		
Additionnal module in Physics	LPHYS100P	5		
Additionnal module in Mathematics	LMATH100P	5		
Minor in Physics	LPHYS100I	5		
Minor in Mathematics	LMATH100I	5		