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Physics from symmetry. (English) Zbl 1330.81005

Undergraduate Lecture Notes in Physics. Cham: Springer (ISBN 978-3-319-19200-0/hbk; 978-3-319-36756-9/pbk; 978-3-319-19201-7/ebook). xix, 279 p. (2015).

The main purpose of this book is to present an updated modern approach to physical theories thorough symmetry methods. It shall not be understood as a pure academical approach like many other monographs on the subject, but as an intuitive approach that tries to introduce and justify the concepts and notions in a natural and physically motivated way, deprived from the formal machinery that usually is at the source of difficulties for the beginner. As a first contact text it is remarkably well written and motivated, and constitutes a very good preparation for the study of the hard formalism of more advanced books.

The book consists of four parts divided into 13 chapters and four appendices. The first part, consisting of two chapters, gives a detailed description of the purpose and motivation of the book, with a short résumé of the notions of Special Relativity required. The diagram on page 5 illustrates quite well the structure of the book. The second part deals with the fundamental properties and features of the semisimple Lie groups $SO(3)$, $SU(2)$ and the Lorentz group, namely the structure of (finite-dimensional) representations and the Casimir operators. Once the Lorentz group has been considered, the Poincaré (it is somewhat irritating that it is written as "Poincare" through the whole book) group is briefly revisited, and a first connection to elementary particles made. In the fourth chapter the Lagrangian formalism is treated. Using the standard motivations from the Calculus of Variations, the Lagrange equations for Field Theories are considered. The main tool in this context, namely the Noether theorem, is analyzed in some detail starting from the corresponding result for discrete systems. Part three of the book emcompasses three chapters. The first one reviews the operator formalism in Quantum Mechanics, as well as the notions of spin and angular momentum. With the Klein-Gordon, Dirac and Prola equations, the basics on the free theory and Lorentz covariance are covered, in order to be applied to the interaction theory, the subject of chapter seven. The $U(1)$ interaction is dealt with in detail, as well as a more brief description for the $SU(2)$ and $SU(3)$ cases. The main conservation laws relevant for the particle classification are presented, and the relation between the underlying statistics discussed. The fourth part, consisting of five chapters, considers applications of the theory. In chapter eight, applications to Quantum Mechanics are considered, specifically, the identification problem, the Schrödinger equation, the Heisenberg uncertainty principle and the Dirac spinors are discussed. Chapter nine is devoted to some questions of QFT. Here the $0, \frac{1}{2}, 1$ Field theories and their interactions are considered. As an appendix, the general solutions of the Klein-Gordon equations are discussed. The three following chapters, dealing with Classical Mechanics, Electrodynamics and Gravity, are quite brief and only consider quite specific topics, which are however quite useful in order to illustrate the range of application of symmetry methods. The appendices review the fundamental notions on Linear Algebra, Calculus and Fourier Analysis used in the text, serving to settle the notation used. The references enumerate a number of canonical texts, most of them devoted to QFT, as well as other introductory and advanced monographs on symmetry methods in physics. Albeit no list of references can be exhaustive, I miss two subject-oriented books that have become classics, namely those of *H. Georgi* [Lie algebras in particle physics. From isospin to unified theories. Reading, Massachusetts, etc.: The Benjamin/Cummings Publishing Company, Inc. (1982; Zbl 0505.00036)] and *R. Gilmore* [Lie groups, Lie algebras, and some of their applications. New York etc.: John Wiley & Sons (1974; Zbl 0279.22001)].

There is no doubt that the text will be useful as an accompanying textbook, it should however be taken into account that some imprecisions can sometimes lead to confusion. To cite only some of these, on page 49 we find a remark that the Lie group $SO(3)$ can be thought intuitively as "half the sphere $\mathbb{S}^3$". This is at least an awkward interpretation of the space $P_3(\mathbb{R})$. Further, it is not explicitly stated in the text that most of the multiplets used are considered over the complex field. This is however a relevant point, as the diagonal vs. diagonalizable character of an operatior depends essentially on the base field. In this context, the Schur Lemma does not imply that an operator commuting with a representation is a multiple of the identity operator; this holds for complex but not for real representations. A third point where a clumsy intuition can be found is on page 87, when commenting on the notion of manifold. These are

however minor defects that do not alter the value of the book. Summarizing, despite these isolated exotic interpretations, this book describes rather well the not always easy to understand subject of symmetry methods in physics, and will be a valuable addition to the bibliography for any interested reader, and even for the expert, with an alternative point of view.

Reviewer: Rutwig Campoamor-Stursberg (Madrid)

MSC:

81-01	Introductory exposition (textbooks, tutorial papers, etc.) pertaining to quantum theory
81P05	General and philosophical questions in quantum theory
81Q60	Supersymmetry and quantum mechanics
83-01	Introductory exposition (textbooks, tutorial papers, etc.) pertaining to relativity and gravitational theory
78-01	Introductory exposition (textbooks, tutorial papers, etc.) pertaining to optics and electromagnetic theory
70-01	Introductory exposition (textbooks, tutorial papers, etc.) pertaining to mechanics of particles and systems
22E70	Applications of Lie groups to the sciences; explicit representations
00A79	Physics

Keywords:

physics; symmetry; field theory

Full Text: DOI