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Chapter 1 : W. K. Tung Group theory in physics : problems and solutions in SearchWorks catalog

Group theory is beautiful and logical, and Professor Tung's exposition is concise and elegant. He doesn't waste any words and the notation is dense, which also seems to upset some of the other reviewers, but hey, that's math for you.

Physics[edit] In physics , groups are important because they describe the symmetries which the laws of physics seem to obey. Physicists are very interested in group representations, especially of Lie groups, since these representations often point the way to the "possible" physical theories. Chemistry and materials science[edit] In chemistry and materials science , groups are used to classify crystal structures , regular polyhedra, and the symmetries of molecules. Molecular symmetry is responsible for many physical and spectroscopic properties of compounds and provides relevant information about how chemical reactions occur. In order to assign a point group for any given molecule, it is necessary to find the set of symmetry operations present on it. The symmetry operation is an action, such as a rotation around an axis or a reflection through a mirror plane. In other words, it is an operation that moves the molecule such that it is indistinguishable from the original configuration. In group theory, the rotation axes and mirror planes are called "symmetry elements". These elements can be a point, line or plane with respect to which the symmetry operation is carried out. The symmetry operations of a molecule determine the specific point group for this molecule. Water molecule with symmetry axis In chemistry , there are five important symmetry operations. The identity operation E consists of leaving the molecule as it is. This is equivalent to any number of full rotations around any axis. This is a symmetry of all molecules, whereas the symmetry group of a chiral molecule consists of only the identity operation. Rotation around an axis Cn consists of rotating the molecule around a specific axis by a specific angle. Other symmetry operations are: History of group theory Group theory has three main historical sources: Early results about permutation groups were obtained by Lagrange , Ruffini , and Abel in their quest for general solutions of polynomial equations of high degree. In geometry, groups first became important in projective geometry and, later, non-Euclidean geometry. Galois , in the s, was the first to employ groups to determine the solvability of polynomial equations. Arthur Cayley and Augustin Louis Cauchy pushed these investigations further by creating the theory of permutation groups. The second historical source for groups stems from geometrical situations. In an attempt to come to grips with possible geometries such as euclidean , hyperbolic or projective geometry using group theory, Felix Klein initiated the Erlangen programme. Sophus Lie , in , started using groups now called Lie groups attached to analytic problems. Thirdly, groups were, at first implicitly and later explicitly, used in algebraic number theory. The different scope of these early sources resulted in different notions of groups. The theory of groups was unified starting around Since then, the impact of group theory has been ever growing, giving rise to the birth of abstract algebra in the early 20th century, representation theory , and many more influential spin-off domains. The classification of finite simple groups is a vast body of work from the mid 20th century, classifying all the finite simple groups.

Chapter 2 : Group Theory in Physics

It emphasizes group theory's role as the mathematical framework for describing symmetry properties of classical and quantum mechanical systems. Familiarity with basic group concepts and techniques is invaluable in the education of a modern-day physicist.

To generate this group, start with a 4-fold axis and one reflection plane. Draw a diagram like the one for C3v. The reflections are also divided into two classes, one class in the right angles between members of the other class. There are five classes, and so five irreducible representations. The new one-dimensional representations B1 and B2 appear. The character table is shown at the left. We have already seen some of them above. Consider the function x2 - y2. Show that it is transformed into itself by all group operations, so that it is a basis for a one-dimensional representation. This can be done without algebra, merely by considering the effects of the operations on x and y. To which representation does it belong? A subset of the members of the group may form a group by themselves. This subset must contain the identity E, of course, and the inverses of each member. It is called a subgroup. A subgroup made up of whole classes is called an invariant subgroup. Improper subgroups are the identity E alone and the whole group; all others are proper subgroups. The members of a group that commute with all members of the group form an Abelian subgroup called the center of the group. There are many algebraic results such as these that aid an understanding of the structure of groups, but are not directly applicable to representations. Any representation of a group also gives a representation of a subgroup, but an irreducible representation of the group may give a reducible representation of a subgroup. You should be able to convince yourself that P3 is isomorphic to C3v by setting up a one-to-one correspondence of the members of each group. The diagrams that were presented above may help, if the point P and its images are numbered. Subgroups of Pn are also called permutation groups. For example, the even permutations in Pn those that can be accomplished by an even number of interchanges form a group of order n! In fact, permutation groups were the first ones studied, and there is considerable lore on their representations. The Four Major Theorems Most of the results of matrix representation theory that are useful in physics are derived from the following four theorems. We have already used some of them. Proofs are given in References Any matrix representation of a group is equivalent to some representation by unitary matrices. A matrix that commutes with all matrices of an irreducible representation can only be a multiple of the identity matrix. In the latter case, the inverse M-1 exists, and the representations A, B are equivalent. The sum is over all the members of the group. The deltas are zero when their indices are different, unity when their indices are equal. The scalar product of two vectors is the sum of the products of the individual elements, symbolically written a,b , and is a number, not a vector. The concept can be extended to function spaces where the scalar product is an integral. Applications to Quantum Mechanics The Hamiltonian operator H is a function of the coordinates and momenta of a system. In general, this does not occur except when there is some reason forcing the states to have the same energy, as we shall see. When it occurs without a compelling reason, it is called accidental degeneracy. If Q represents some change of basis functions or coordinates, QHQ-1 is the operator H in the new frame of reference. The set of operators commuting with H is a group, called the symmetry group of the Hamiltonian. Every state can be classified by the irreducible representation to which it belongs, and any coincidence in energy is regarded as accidental, unless the representation is multidimensional, in which case the coincidence in energy is necessary. Spectroscopic classifications are essentially identifications of the irreducible representation to which the state belongs. In this case, previously degenerate levels may split into distinct levels, some of which may still be degenerate. Group theory will provide suitable functions for this calculation that can greatly reduce the effort involved. As long as there is spherical symmetry, these states all have exactly the same energy. If you apply a magnetic field, the spherical symmetry is broken, and there is now only symmetry about an axis in the direction of the magnetic field. Group theory can determine these states in advance, so that the splitting is given by a simple diagonal matrix element. As a second example, the energy levels of the hydrogen atom depend only on the principal quantum number N. As far as the rotation group is concerned, this degeneracy is accidental. In fact, the Hamiltonian is invariant under the four-dimensional rotation group actually, a group isomorphic to the four-dimensional rotation group , and its irreducible representations explain the added degeneracy, which is really not accidental at all. The degeneracy is lifted when the potential has a different radial dependence in more complex atoms, although the spherical symmetry is still there. It was conjectured that they were members of an irreducible representation of dimension 3 of a group called SU3, and that the differences in the observed masses was a splitting due to a perturbation related to the property called strangeness. There was some success in arranging the known particles in irreducible representations of SU3, but later a theory of the internal structure of heavy elementary particles superseded this idea. However, group theory is still quite important in the field. Group theory is good for more than classification, however. This representation is almost always reducible, and the component irreducible representations can be found by character analysis. This gives selection rules for the nonvanishing of certain transitions or of certain matrix elements. An example from spectroscopy might show how this operates. Continuous Groups The finite groups are useful with crystals, molecular spectra, and identical particles, and give clear examples of the applications of group theory, but it will be noticed that we mentioned several continuous groups above in our examples. In fact, such groups play a large role in quantum mechanics and elementary particle physics, and some facts about them should be noted here. Their representations share many of the properties of the representations of finite groups, but the methods of working with the groups is somewhat different. If you have studied quantum mechanics, you have certainly studied angular momentum. This is group theory, but is not usually presented as such in elementary treatments, since everything can be worked out with algebra from first principles. What you find are the irreducible representations of the rotation group in three dimensions, O3, and the rules for combining them. The rotation group O3 is an excellent example of a continuous group, though it is a little too simple to show all the wrinkles. A continuous group is of infinite order, so the sum over finite group elements becomes an integration over continuous group elements, suitably parametrized. For O3, we could use the two angles specifying the orientation of the axis of rotation, and the angle of rotation about this axis. The [] is the commutator of the two operators: As you probably know, the whole theory can be worked out from this. All this comes from the commutation relation! Now the J operators are not the members of a group. Rather, they form a Lie pron. The Lie algebra expresses the structure of the group in a concise and usable form. For many applications of angular momentum, the explicit rotation matrices are not needed. The conservation of angular momentum is a consequence of the O3 symmetry. Quite generally, any continuous symmetry is associated with a conservation law. Linear momentum is similarly related to symmetry under displacement of the system in space, and energy to displacement in time. Finite symmetries are not associated with conserved quantities. Two important symmetries in quantum mechanics are inversion symmetry or parity, and time reversal symmetry. These are both isomorphic to the simple two-member groups that opened our discussion. Time reversal is unusual in that it involves the complex conjugation of the wave function, not simply a linear combination or a multiplication by a constant. Conclusion This paper has covered about the same material as in Schensted, but with different examples and in a somewhat different way. We both have used the groups C2 and C3v as examples, as nearly all accounts do. The references below provide fuller information. No one pays people to do group theory or quantum mechanics. In modern mathematics departments, it seems as unfashionable as complex variables another field that is too difficult these days. It can only be the hobby of a few, and I hope that there are enough minds fascinated by it to preserve it as a living science. No one who is unprepared is likely to make anything of the literature in the field. Much of the recent literature is not worth reading. There is still much to be known, but very little progress has been made recently. Collapse of the foundations will make further progress very difficult. There is a search now for the Higgs boson; contemplate how few people have the faintest idea of what this means. It involves symmetry breaking, incidentally. References This is very restricted set of many references on this subject, containing only those that I regard as the most informative. Further references may be found in these works. All of these authors clearly desired to communicate their knowledge and tried their best to do it, unlike most more recent authors. Probably now unavailable, this was a remarkably clear and economical exposition. A classic reference, but not easy reading for the uninitiated. Schonland, Molecular Symmetry London: Very clearly written with many examples and few divergences from the task of explaining the application to molecular spectra.

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Slansky, Group theory for unified model building , Physics Reports 79 Course Requirements The basic course requirements consist of four problem sets, which will be handed out during the quarter, and a term project. There will be no exams. Due to the limited time in a quarter, it will be impossible to do more than sketch some of the most basic applications of group theory to modern physics. To encourage students to delve deeper, all students will be required to complete a term project based on their reading of a particular topic in group theory and its applications to physics. The project may be presented orally or in written form at the end of the term. Oral presentations are encouraged since they will benefit all members of the class. Please follow the following schedule: Initial choice of topic for term May 2 Short written proposal for term May 9 Oral Presentation of term project June 14 Written version of term project All projects should include a one page bibliography containing references pertinent to the project. Copies of this bibliography should be made available to all students in the class. If an oral presentation is not possible not the preferred option , a full written version of the project is an acceptable substitute. Disability Statement to Students in Class UC Santa Cruz is committed to creating an academic environment that supports its diverse student body. If you have not already done so, I encourage you to learn more about the many services offered by the DRC. You can visit their website http: The phone number is or email drc ucsc. UC Santa Cruz is committed to creating an academic environment that supports its diverse student body. If you are a student with a disability who requires accommodations to achieve equal access in this course, please submit your Accommodation Authorization Letter from the Disability Resource Center DRC to me privately during my office hours or by appointment, preferably within the first two weeks of the quarter. At this time, we would also like us to discuss ways we can ensure your full participation in the course. We encourage all students who may benefit from learning more about DRC services to contact DRC by phone at or by email at drc ucsc.

Chapter 4 : Physics Home Page

An introductory text book for graduates and advanced undergraduates on group representation theory. It emphasizes group theory's role as the mathematical framework for describing symmetry properties of classical and quantum mechanical systems.

Familiarity with basic group concepts and techniques is invaluable in the education of a modern-day physicist. This book emphasizes general features and methods which demonstrate the power of the group-theoretical approach in exposing the systematics of physical systems with associated symmetry. Particular attention is given to pedagogy. In developing the theory, clarity in presenting the main ideas and consequences is given the same priority as comprehensiveness and strict rigor. To preserve the integrity of the mathematics, enough technical information is included in the appendices to make the book almost self-contained. A set of problems and solutions has been published in a separate booklet. By on Jun 16, This book gives an excellent introduction into group theory and provides a working knowledge for those who want to study field theory for example. I especially like the complete treatment of representations of the classical groups and the Lorentz and Poincare groups. I got it after struggling with some books on quantum field theory and finding myself unable to answer basic self-asked questions like "what is a spinor? I went through the first 8 chapters and will go back and finish it some day. If you would like to learn the essentials of the groups used in physics, this book will do the trick. You can then go back to the physics books for the applications. I was only able to find a single typo! He can do better. By Hui Fang on Jan 14, This is not a bad book. The contents are comprehensive. The theorems are well proved. Graphs are used appropriatly to clarify the concept. But it has several shortcomings. One is the line space is too small, too many words are clustered together. Another is sometimes the proofs are too short. Some explanation should be given on certain points because those points are not so obvious and should not be taken for granted. Frankly, I love group theory, but after reading this book for 20 pages, I felt very tired, both because of the bad format and hard thinking. An excellent presentation of group theory in physics By Gv on Sep 28, I got to this book at a time when I was interested in a presentation of the method of induced representations, of fundamental importance for quantum physics because it allows a systematical derivation of the fields consistent with a given Lie group, so that it is of basic importance for quantum field theory. Of course, I went through many other parts of this book, and I found it excellently written by a person who loves this subject and who strived and succeeded to patiently present it all, gradually, from simple to complex and in a very clear and coherent exposition from beginning to end. I am delighted by it. It was very useful to me. By the way, I was directed to this book by the bibliography given in a chapter of the outstanding The Quantum Theory of Fields, Volume 1: Foundations by Steven Weinberg. Hello, ever hear of the Standard Model? Special unitary groups are only mentioned in passing. Not even a hint of the exceptional groups. Foundations, and does indeed have a useful treatment of Lorentz transformations and angular momentum. I found the preliminary part of the book that constitutes chapters , however, hard to follow, with proofs that were too cryptic for me to understand. One brief section in this book that I particularly liked was the discussion of doubly connected curves, a concept that I had encountered in other books, but did not understand. I have included jpeg files for these pages in this review. This particular edition is in a Paperback format. It was published by World Scientific Publishing Company and has a total of pages in the book. To buy this book at the lowest price, Click Here.

Chapter 5 : Group Theory and Physics

Group Theory in Physics: Problems and Solutions by Wu-ki Tung, Michael Aivazis This solutions booklet is a supplement to the text book 'Group Theory in Physics' by Wu-Ki Tung. It will be useful to lecturers and students taking the subject as detailed solutions are given.

Chapter 6 : Group Theory in Physics - Wu-Ki Tung - Google Books

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Supplementary notes ; The following files contain detailed mathematical derivation of Tung's textbook. Both nb & pdf versions contain the same content.

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Chapter 8 : Group theory - Wikipedia

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