INTRODUCTION TO TENSORS AND GROUP THEORY FOR PHYSICISTS pdf

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"Jeevanjee 's An Introduction to Tensors and Group Theory for Physicists is a valuable piece of work on several counts, including its express pedagogical service.

In that literature, the above equation is often part of the definition of a second rank tensor; here, though, we see that its form is really just a consequence of multilinearity. This fact is crucial in getting a feel for tensors and what they mean. Another nice feature of our definition of a tensor is that it allows us to derive the tensor transformation laws which historically were taken as the definition of a tensor. Here, the transformation law is another consequence of multilinearity! One common source of confusion is that in physics textbooks, tensors usually of the second rank are often represented as matrices, so then the student wonders what the difference is between a matrix and a tensor. Above, we have defined a tensor as a multilinear function on a vector space. What does that have to do with a matrix? Thus, once a basis is chosen, the action of T can be neatly expressed using the corresponding matrix [T]. It is crucial to keep in mind, though, that this association between a tensor and a matrix depends entirely on a choice of basis, and that [T] is useful mainly as a computational tool, not a conceptual handle. T is best thought of abstractly as a multilinear function, and [T] as its representation in a particular coordinate system. One possible objection to our approach is that matrices and tensors are often thought of as linear operators which take vectors into vectors, as opposed to objects which eat vectors and spit out numbers. It turns out, though, that for a second rank 6 1 A Quick Introduction to Tensors tensor these two notions are equivalent. You can also easily check that TR is multilinear, i. This makes it obvious how to turn a linear operator R into a second rank tensorâ€"just sandwich the component matrix in between two vectors! This whole process is also reversible: One can check that these processes are inverses of each other, so this sets up a one-to-one correspondence between linear operators and second rank tensors and we can thus regard them as equivalent. Since the matrix form of both is identical, one often does not bother trying to clarify exactly which one is at hand, and often times it is just a matter of interpretation. How does all this work in a physical context? One nice example is the rank 2 moment-of-inertia tensor I, familiar from rigid body dynamics in classical mechanics. From this expression, most textbooks then figure out how the Iij must transform under a change of coordinates, and this behavior under coordinate change is then what identifies the Iij as a tensor. In this text, though, we will take a different point of view. We can then think of I as a second rank tensor defined by 1 1. As mentioned above, one can also interpret I as a linear operator which takes vectors into vectors. The two definitions are equivalent. Many other tensors which we will consider in this text are also nicely understood as multilinear functions which happen to have convenient component and matrix representations. These include the electromagnetic field tensor of electrodynamics, as well as the metric tensors of Newtonian and relativistic mechanics. As we progress we will see how we can use our new point of view to get a handle on these usually somewhat enigmatic objects. Chapter 2 Vector Spaces Since tensors are a special class of functions defined on vector spaces, we must have a good foundation in linear algebra before discussing them. This chapter starts with the familiar material about vectors, bases, linear operators etc. As we lay this groundwork, hopefully you will find that our slightly more abstract viewpoint also clarifies the nature of many of the objects in physics you have already encountered. We are taught as undergraduates to think of vectors as arrows with a head and a tail, or as ordered triples of real numbers, but physics, and especially quantum mechanics, requires a more abstract notion of vectors. Before reading the definition of an abstract vector space, keep in mind that the definition is supposed to distill all the essential features of vectors as we know them like addition and scalar multiplication while detaching the notion of a vector space from specific constructs, like ordered n-tuples of real or complex numbers denoted as Rn and Cn , respectively. The mathematical utility of this is that much of what we know about vector spaces depends only on the essential properties of addition and scalar multiplication, not on other properties particular to Rn or Cn. If we work in the abstract framework and then come across other mathematical objects that do not look like Rn or Cn but that are abstract vector spaces, then most everything we know about Rn and Cn will apply to these spaces as well. Physics also forces us to use the abstract definition since many quantum-mechanical vector spaces are infinite-dimensional and cannot be viewed as Cn or Rn for any n. An added dividend of the abstract approach is that we will learn to think about vector spaces independently of any basis, which will prove very useful. In determining whether a set is a vector space or not, one is usually most concerned with defining addition in such a way that the set is closed under addition and that axioms 3 and 4 are satisfied; most of the other axioms are so natural and obviously satisfied that one, in practice, rarely bothers to check them. Addition and scalar multiplication are defined in the usual way: You should check that the axioms are satisfied. These spaces, of course, are basic in physics; R3 is our usual three-dimensional cartesian space, R4 is spacetime in special relativity, and Rn for higher n occurs in classical physics as configuration spaces for multiparticle systems for example, R6 is the configuration space in the 1 Another word about axioms 3 and 4, for the mathematically inclined feel free to skip this if you like: Note, however, that Cn is a complex vector space, i. This seemingly pedantic distinction can often end up being significant, as we will see. The same definitions are used for Mn C , which is of course a complex vector space. You can again check that the axioms are satisfied. Though these vector spaces do not appear explicitly in physics very often, they have many important subspaces, one of which we consider in the next example. The converse, of course, is not true. One interesting thing about Hn C is that even though the entries of its matrices can be complex, it does not form a complex vector space; multiplying a Hermitian matrix by i yields an anti-Hermitian matrix, so Hn C is not closed under complex scalar multiplication. As far as physical applications go, we know that physical observables in quantum mechanics are represented by Hermitian operators, and if we are dealing with a finite-dimensional ket space such as those mentioned in Example 2. Note that if we considered only real-valued functions then we would only have a real vector space. Verifying the axioms is straightforward though not entirely trivial, as one must show that the sum of two square-integrable functions is again square-integrable Problem 2. This vector space arises in quantum mechanics as the set of normalizable wavefunctions for a particle in a one-dimensional infinite potential well. This vector space is denoted as L2 R. Addition and complex scalar multiplication are defined in the usual 2. You may be surprised to learn that the spherical harmonics of degree l are essentially elements of Hl R3! Conversely, if we take a degree l spherical harmonic and multiply it by r l , the result is a harmonic function. A derivation and further discussion can be found in any electrodynamics or quantum mechanics book, like Sakurai [14]. Spherical harmonics are discussed further throughout this text; for a complete discussion, see Sternberg [16]. In this section we will make this idea precise and describe bases for some of the examples in the previous section. First, we need the notion of the span of a set of vectors. Such vectors are known as linear combinations of the vi , so Span S is just the set of all linear combinations of the vectors in S. If S has infinitely many elements then the span of S is again all the linear combinations of vectors in S, though in this case the linear combinations can have an arbitrarily large but finite number of terms. If S is not linearly dependent then we say it is linearly independent, and in this case no vector in S can be written as a linear combination of any others. This means, roughly speaking, that a basis has enough vectors to make all the others, but no more than that. The reasons for this will become clear as we progress. One can show7 that all finite bases must have the same number of elements, so we define the dimension of a vector space V , denoted dim V , to be the number of elements of any finite basis. If no finite basis exists, then we say that V is infinitedimensional. Also, we should mention that basis vectors are often denoted ei rather than vi , and we will use this notation from now on. You should check that this is indeed a basis, and thus that the dimension of Rn is, unsurprisingly, n. More on this later.

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2: An Introduction to Tensors and Group Theory for Physicists

The second edition of this highly praised textbook provides an introduction to tensors, group theory, and their applications in classical and quantum physics. Both intuitive and rigorous, it aims to demystify tensors by giving the slightly more abstract but conceptually much clearer definition found.

Physics and Maths Graduates Rating: Mike James Both tensors and groups are at the foundation of modern physics and many aspects of computing. This is a book for graduate students of math and physics - but mostly physics. If you have tried to master tensors and group theory as they apply to modern physics you may well have been horrified by the brutal abstract math approach of the typical book. Both subjects lend themselves well to the theorem proof with no kind word to help you understand how it all fits together or why you are even doing all of it. This book is a lot better, but not perfect. In plain terms there is still room for a book on both of these topics that explains what it is all about first and then presents the math to back it all up. The book divides into two parts - first we have a long introduction to linear algebra and tensors and then the second main topic is groups. Before we get to the details there is a short "this is a tensor" chapter. This sets the scene and motivates much of what follows and basically says a tensor is a multilinear function - from which everything else follows. So chapter 2 starts working through the standard ideas - span, basis, dual space etc. The approach is for the physicist because spaces of matrices are introduced along with specific examples such as the Pauli matrices. Theoretical difficulties with infinite dimensional spaces are glossed over, thankfully and examples of function spaces are included. The angular momentum operators are introduced very early and of course there is a very real sense in which all of this theory is motivated by angular momentum and spin. By the end of the chapter we have covered real and complex inner product spaces. Next we have tensors. Given that dual spaces have already been introduced we have definitions of covariance and contravariance, but without relating the ideas to the physical reasons why some things are best treated as covariance and other as contravariant. The ideas go deeper than the mathematics presented here. On to cover the tensor product and symmetric and antisymmetric spaces. This is not only useful for general physics but it is what you have to master to fully understand quantum computing which goes on in the product space of qubits. This brings the first part of the book to a close. It is short and not too theorem-proof bound to be impossible to understand. If you do read it then be prepared to think quite hard about some of the examples which tend to be more advanced than the main text. The second part of the book dives into groups without too much motivation. The whole aim is to get on to Lie groups as quickly as possible. I can imagine that if this is your first introduction to groups it might be too fast. The second problem is that the important groups of classical and quantum physics are introduced equally quickly and the problem is that there is no complete list of symbols. What this means is that you inevitably end up having to go back and discover what SL or M is. Not too much of a problem, unless this is your first exposure to the nomenclature and you read the book in short bursts. From here we move on to Lie algebra and its key ideas, such as the exponential map and so on. If you are prepared for it then the book will get you to understand that the Lie algebra is the infinitesimal form of the group, the tangent space of the group as a manifold and that the connection between the infinitesimal and the macro is the exponential map. However it is still possible to get lost in the detail. Once we have the basics over the next topic is representation theory. This is introduced with very little motivation. The point being that the we have to have the same symmetries in the spaces that our models occupy as the real world. Of course, today this has been turned around and we suppose that any valid symmetry of the model is also a symmetry of the real world. It is in this sense that representation theory has become quantum mechanics. This is the least satisfactory part of the book, but still better than many others - it just needs more lower level motivation. Conclusion Overall, this is a good read but mainly if you already know the motivations behind what is going on. There is a long term trend in physics textbooks to move in the direction of mathematical textbooks. The whole point of physics is to say something about the real world and expressing everything in abstract symbols

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in theorem-proof form may say it but only in a whisper. We need to be much clearer about what the actual physics is the math is expressing. While this book only succumbs to math envy for part of its length, it could still add more physics to the math. Related Articles and Reviews.

3: An Introduction to Tensors and Group Theory for Physicists - PDF Free Download

Introduction to Group Theory for Physicists Marina von Steinkirch State University of New York at Stony Brook steinkirch@www.enganchecubano.com January 12,

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The second edition of this highly praised textbook provides an introduction to tensors, group theory, and their applications in classical and quantum physics. Both intuitive and rigorous, it aims to.

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