

Selected Solutions for *An Introduction to Tensors and Group Theory for Physicists, 2nd ed.*

October 3, 2018

Introduction

This is an incomplete, evolving solutions manual to [Jee15]. Note that this is the second edition of this text, and that exercise and problem numbering differs between editions. Solutions posted here have primarily been written by students in courses I taught in the UC Berkeley Physics department between 2012 and 2016. If you are interested in improving existing solutions or adding new ones of your own, please email me at nadirj@princeton.edu.

1 A Quick Introduction to Tensors

2 Vector Spaces

Exercise 2.1 : Verify equation 2.7, which states

$$\Delta_{S^2} Y(\theta, \phi) = -l(l+1)Y(\theta, \phi).$$

Solution: Pick a vector $f \in \mathcal{H}_l(\mathbb{R}^3)$. This function has two useful properties: in spherical coordinates, we may write our function as $f(r, \theta, \phi) = r^l Y(\theta, \phi)$ – this is a property of $P_l(\mathbb{R}^3)$, which contains $\mathcal{H}_l(\mathbb{R}^3)$ as a subspace. And, since we have chosen it from $\mathcal{H}_l(\mathbb{R}^3)$, it satisfies $\Delta f = 0$. We write the Laplacian explicitly and combine terms

$$\begin{aligned}\Delta f &= \left(\frac{\partial^2}{\partial r^2} + \frac{2}{r} \frac{\partial}{\partial r} + \frac{1}{r^2} \Delta_{S^2} \right) r^l Y(\theta, \phi) \\ &= l(l+1)r^{l-2}Y + \frac{2}{r}lr^{l-1}Y + r^{l-2}\Delta_{S^2}Y \\ &= l(l+1)r^{l-2}Y + 2lr^{l-2}Y + r^{l-2}\Delta_{S^2}Y \\ &= l(l+1)r^{l-2}Y + r^{l-2}\Delta_{S^2}Y\end{aligned}$$

But we know this quantity is equal to zero. Therefore,

$$\Delta_{S^2} Y(\theta, \phi) = -l(l+1)Y(\theta, \phi)$$

as claimed. Thus all harmonic l -degree polynomials correspond to a matching spherical harmonic, which corresponds to the restriction of the said polynomial to the unit sphere.

Exercise 2.3 : Given a vector v and a finite basis $\mathcal{B} = \{e_i\}_{i=1,\dots,n}$, show that the expression of v as a linear combination of the e_i is unique.

Solution: Suppose that our representation of v in the basis $\mathcal{B}$ is explicitly given by $v = a^i e_i$, where the a^i are scalars in the appropriate field. Now, suppose that there exists another representation of v in the same basis, given by $v = b^i e_i$. Then we may write:

$$\begin{aligned}v - v &= 0 \\ &= a^i e_i - b^i e_i \\ &= (a^i - b^i) e_i\end{aligned}$$

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