

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:

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

Group Theory Solution Manual

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Table of Contents Group Theory Solution Manual

1. Understanding the eBook Group Theory Solution Manual
 - The Rise of Digital Reading Group Theory Solution Manual
 - Advantages of eBooks Over Traditional Books
2. Identifying Group Theory Solution Manual
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in a Group Theory Solution Manual
 - User-Friendly Interface
4. Exploring eBook Recommendations from Group Theory Solution Manual
 - Personalized Recommendations
 - Group Theory Solution Manual User Reviews and Ratings
 - Group Theory Solution Manual and Bestseller Lists

5. Accessing Group Theory Solution Manual Free and Paid eBooks
 - Group Theory Solution Manual Public Domain eBooks
 - Group Theory Solution Manual eBook Subscription Services
 - Group Theory Solution Manual Budget-Friendly Options
6. Navigating Group Theory Solution Manual eBook Formats
 - ePub, PDF, MOBI, and More
 - Group Theory Solution Manual Compatibility with Devices
 - Group Theory Solution Manual Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Group Theory Solution Manual
 - Highlighting and Note-Taking Group Theory Solution Manual
 - Interactive Elements Group Theory Solution Manual
8. Staying Engaged with Group Theory Solution Manual
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Group Theory Solution Manual
9. Balancing eBooks and Physical Books Group Theory Solution Manual
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Group Theory Solution Manual
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Group Theory Solution Manual
 - Setting Reading Goals Group Theory Solution Manual
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Group Theory Solution Manual
 - Fact-Checking eBook Content of Group Theory Solution Manual
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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