

# 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.

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**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 Solutions Manual

**JS Bruner**



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## **Table of Contents Group Theory Solutions Manual**

1. Understanding the eBook Group Theory Solutions Manual
  - The Rise of Digital Reading Group Theory Solutions Manual
  - Advantages of eBooks Over Traditional Books
2. Identifying Group Theory Solutions 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 an Group Theory Solutions Manual
  - User-Friendly Interface
4. Exploring eBook Recommendations from Group Theory Solutions Manual
  - Personalized Recommendations

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