

## Chapter One

1.  $AC\{D, B\} = ACDB + ACBD$ ,  $A\{C, B\}D = ACBD + ABCD$ ,  $C\{D, A\}B = CDAB + CADB$ , and  $\{C, A\}DB = CADB + ACDB$ . Therefore  $-AC\{D, B\} + A\{C, B\}D - C\{D, A\}B + \{C, A\}DB = -ACDB + ABCD - CDAB + ACDB = ABCD - CDAB = [AB, CD]$

In preparing this solution manual, I have realized that problems 2 and 3 in are misplaced in this chapter. They belong in Chapter Three. The Pauli matrices are not even defined in Chapter One, nor is the math used in previous solution manual. - *Jim Napolitano*

2. (a)  $\text{Tr}(X) = a_0 \text{Tr}(1) + \sum_i \text{Tr}(\sigma_i) a_i = 2a_0$  since  $\text{Tr}(\sigma_i) = 0$ . Also  $\text{Tr}(\sigma_k X) = a_0 \text{Tr}(\sigma_k) + \sum_i \text{Tr}(\sigma_k \sigma_i) a_i = \frac{1}{2} \sum_i \text{Tr}(\sigma_k \sigma_i + \sigma_i \sigma_k) a_i = \sum_i \delta_{ki} \text{Tr}(1) a_i = 2a_k$ . So,  $a_0 = \frac{1}{2} \text{Tr}(X)$  and  $a_k = \frac{1}{2} \text{Tr}(\sigma_k X)$ . (b) Just do the algebra to find  $a_0 = (X_{11} + X_{22})/2$ ,  $a_1 = (X_{12} + X_{21})/2$ ,  $a_2 = i(-X_{21} + X_{12})/2$ , and  $a_3 = (X_{11} - X_{22})/2$ .

3. Since  $\det(\boldsymbol{\sigma} \cdot \mathbf{a}) = -a_x^2 - (a_y^2 + a_z^2) = -|\mathbf{a}|^2$ , the cognoscenti realize that this problem really has to do with rotation operators. From this result, and (3.2.44), we write

$$\det \left[ \exp \left( \pm \frac{i \boldsymbol{\sigma} \cdot \hat{\mathbf{n}} \phi}{2} \right) \right] = \cos \left( \frac{\phi}{2} \right) \pm i \sin \left( \frac{\phi}{2} \right)$$

and multiplying out determinants makes it clear that  $\det(\boldsymbol{\sigma} \cdot \mathbf{a}') = \det(\boldsymbol{\sigma} \cdot \mathbf{a})$ . Similarly, use (3.2.44) to explicitly write out the matrix  $\boldsymbol{\sigma} \cdot \mathbf{a}'$  and equate the elements to those of  $\boldsymbol{\sigma} \cdot \mathbf{a}$ . With  $\hat{\mathbf{n}}$  in the  $z$ -direction, it is clear that we have just performed a rotation (of the spin vector) through the angle  $\phi$ .

4. (a)  $\text{Tr}(XY) \equiv \sum_a \langle a | XY | a \rangle = \sum_a \sum_b \langle a | X | b \rangle \langle b | Y | a \rangle$  by inserting the identity operator. Then commute and reverse, so  $\text{Tr}(XY) = \sum_b \sum_a \langle b | Y | a \rangle \langle a | X | b \rangle = \sum_b \langle b | Y X | b \rangle = \text{Tr}(YX)$ .

(b)  $XY|\alpha\rangle = X[Y|\alpha\rangle]$  is dual to  $\langle\alpha|(XY)^\dagger$ , but  $Y|\alpha\rangle \equiv |\beta\rangle$  is dual to  $\langle\alpha|Y^\dagger \equiv \langle\beta|$  and  $X|\beta\rangle$  is dual to  $\langle\beta|X^\dagger$  so that  $X[Y|\alpha\rangle]$  is dual to  $\langle\alpha|Y^\dagger X^\dagger$ . Therefore  $(XY)^\dagger = Y^\dagger X^\dagger$ .

(c)  $\exp[i f(A)] = \sum_a \exp[i f(A)] |a\rangle \langle a| = \sum_a \exp[i f(a)] |a\rangle \langle a|$

(d)  $\sum_a \psi_a^*(\mathbf{x}') \psi_a(\mathbf{x}'') = \sum_a \langle \mathbf{x}' | a \rangle^* \langle \mathbf{x}'' | a \rangle = \sum_a \langle \mathbf{x}'' | a \rangle \langle a | \mathbf{x}' \rangle = \langle \mathbf{x}'' | \mathbf{x}' \rangle = \delta(\mathbf{x}'' - \mathbf{x}')$

5. For basis kets  $|a_i\rangle$ , matrix elements of  $X \equiv |\alpha\rangle \langle \beta|$  are  $X_{ij} = \langle a_i | \alpha \rangle \langle \beta | a_j \rangle = \langle a_i | \alpha \rangle \langle a_j | \beta \rangle^*$ . For spin-1/2 in the  $|\pm z\rangle$  basis,  $\langle + | S_x = \hbar/2 \rangle = 1$ ,  $\langle - | S_x = \hbar/2 \rangle = 0$ , and, using (1.4.17a),  $\langle \pm | S_x = \hbar/2 \rangle = 1/\sqrt{2}$ . Therefore

$$|S_x = \hbar/2\rangle \langle S_x = \hbar/2| \doteq \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 0 & 0 \end{pmatrix}$$

6.  $A[|i\rangle + |j\rangle] = a_i|i\rangle + a_j|j\rangle \neq [|i\rangle + |j\rangle]$  so in general it is not an eigenvector, unless  $a_i = a_j$ . That is,  $|i\rangle + |j\rangle$  is not an eigenvector of  $A$  unless the eigenvalues are degenerate.

# Sakurai Quantum Mechanics 2nd Edition Instructor Manual

**Christian Drosten**



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## **Table of Contents Sakurai Quantum Mechanics 2nd Edition Instructor Manual**

1. Understanding the eBook Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  - The Rise of Digital Reading Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  - Advantages of eBooks Over Traditional Books
2. Identifying Sakurai Quantum Mechanics 2nd Edition Instructor 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 Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  - User-Friendly Interface
4. Exploring eBook Recommendations from Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  - Personalized Recommendations
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual User Reviews and Ratings
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual and Bestseller Lists
5. Accessing Sakurai Quantum Mechanics 2nd Edition Instructor Manual Free and Paid eBooks
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual Public Domain eBooks
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual eBook Subscription Services
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual Budget-Friendly Options
6. Navigating Sakurai Quantum Mechanics 2nd Edition Instructor Manual eBook Formats

- ePub, PDF, MOBI, and More
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual Compatibility with Devices
  - Sakurai Quantum Mechanics 2nd Edition Instructor Manual Enhanced eBook Features
7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Highlighting and Note-Taking Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Interactive Elements Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  8. Staying Engaged with Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  9. Balancing eBooks and Physical Books Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Sakurai Quantum Mechanics 2nd Edition Instructor Manual
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Setting Reading Goals Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Sakurai Quantum Mechanics 2nd Edition Instructor Manual
    - Fact-Checking eBook Content of Sakurai Quantum Mechanics 2nd Edition Instructor 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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