

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 ϕ .

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 $\text{Tr}(XY) = \sum_b \sum_a \langle b | Y | a \rangle \langle a | X | b \rangle = \sum_b \langle b | YX | b \rangle = \text{Tr}(YX)$.

(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) $\exp[if(A)] = \sum_a \exp[if(A)]|a\rangle\langle a| = \sum_a \exp[if(a)]|a\rangle\langle a|$

(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 $|\alpha_i\rangle$, matrix elements of $X \equiv |\alpha\rangle\langle\beta|$ are $X_{ij} = \langle\alpha_i|\alpha\rangle\langle\beta|a_j\rangle = \langle\alpha_i|\alpha\rangle\langle a_j|\beta\rangle^*$. 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.

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