

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) $\mathsf{Tr}(X) = a_0 \mathsf{Tr}(1) + \sum_\ell \mathsf{Tr}(\sigma_\ell) a_\ell = 2a_0$ since $\mathsf{Tr}(\sigma_\ell) = 0$. Also $\mathsf{Tr}(\sigma_k X) = a_0 \mathsf{Tr}(\sigma_k) + \sum_\ell \mathsf{Tr}(\sigma_k \sigma_\ell) a_\ell = \frac{1}{2}\sum_\ell \mathsf{Tr}(\sigma_k\sigma_\ell + \sigma_\ell\sigma_k) a_\ell = \sum_\ell \delta_{k\ell} \mathsf{Tr}(1) a_\ell = 2a_k$. So, $a_0 = \frac{1}{2}\mathsf{Tr}(X)$ and $a_k = \frac{1}{2}\mathsf{Tr}(\sigma_k X)$. (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 $\det(\boldsymbol{\sigma} \cdot \mathbf{a}) = -a_z^2 - (a_x^2 + a_y^2) = -|\mathbf{a}|^2$, 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.

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4. (a) $\mathsf{Tr}(XY) \equiv \sum_a \langle a|XY|a\rangle = \sum_a \sum_b \langle a|X|b\rangle\langle b|Y|a\rangle$ by inserting the identity operator. Then commute and reverse, so $\mathsf{Tr}(XY) = \sum_b \sum_a \langle b|Y|a\rangle\langle a|X|b\rangle = \sum_b \langle b|YX|b\rangle = \mathsf{Tr}(YX)$.
(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 $|a_i\rangle$, 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, $\langle +|S_z = \hbar/2\rangle = 1$, $\langle -|S_z = \hbar/2\rangle = 0$, and, using (1.4.17a), $\langle \pm|S_x = \hbar/2\rangle = 1/\sqrt{2}$. Therefore

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

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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