QM2 Concept Test 9.5

The lowest energy level of the unperturbed Hamiltonian $\hat{H}^0$ is two fold degenerate. i.e., $\hat{H}^0{\psi_{1a}}^0 = {E_1}^0{\psi_{1a}}^0$, $\hat{H}^0{\psi_{1b}}^0 = {E_1}^0{\psi_{1b}}^0$, $\left\langle {\psi_{1a}}^0 \middle| {\psi_{1b}}^0 \right\rangle = 0$. If the first order correction to the energy ${E_1}^1$ can be calculated by ${E_1}^1 = \left\langle \alpha{\psi_{1a}}^0 + \beta{\psi_{1b}}^0 \middle| \hat{H}' \middle| \alpha{\psi_{1a}}^0 + \beta{\psi_{1b}}^0 \right\rangle$, the state $\alpha{\psi_{1a}}^0 + \beta{\psi_{1b}}^0$ is called a "good" state where α and β are complex numbers. Choose all of the following statements that are correct. (Assume the first order correction to the energy is not zero).

1) A "good" state is a stationary state of the unperturbed system $\hat{H}^0$.
2) The perturbed system $\hat{H}^0 + \hat{H}'$ has only two different "good" states $\alpha{\psi_{1a}}^0 + \beta{\psi_{1b}}^0$ since the unperturbed state is two fold degenerate. (Ignore the overall phase.)
3) The different "good" states $\alpha{\psi_{1a}}^0 + \beta{\psi_{1b}}^0$ for the perturbed system $\hat{H}^0 + \hat{H}'$ are orthogonal to each other.

A. 1 only B. 3 only c. 1 and 2 only D. 1 and 3 only E. All of the above

QM2 Concept Test 9.6

Suppose the eigenstates $|a\rangle$, $|b\rangle$, and $|c\rangle$ of $\hat{H}^0$ are 3-fold degenerate and a perturbation $\hat{H}'$ acts on this system. Choose all of he following statements that are correct if $|a\rangle$, $|b\rangle$, and $|c\rangle$ form a "good" basis for the perturbed system.
(Define $\langle i|\hat{H}'|j\rangle = H'_{ij}$).

1) $H'_{aa} = H'_{bb} = H'_{cc}$
2) $H'_{ab} = H'_{bc} = H'_{ca} = 0$
3) $|a\rangle$, $|b\rangle$, and $|c\rangle$ are orthogonal to each other.

A. 1 only B. 2 only C. 1 and 3 only D. 2 and 3 only
E. All of the above

QM2 Concept Test 9.7

Consider the Hamiltonian $\hat{H}^0 + \hat{H}' = V_0 \begin{pmatrix} 1-\varepsilon & 0 & 0 \\ 0 & 1 & \varepsilon \\ 0 & \varepsilon & 2 \end{pmatrix}$, where $\varepsilon \ll 1$.

The basis vectors for the matrix in the order $|a\rangle$, $|b\rangle$, and $|c\rangle$ are the energy eigenstates of the unperturbed Hamiltonian $\hat{H}^0$ ($\varepsilon = 0$). Choose all of the following statements that are correct about the <u>unperturbed</u> system.

1) The distinct energies of the unperturbed system are V_0 and $2V_0$.
2) The energy eigenstates of $\hat{H}^0$ are two fold degenerate with energy V_0.
3) The $\hat{H}^0$ matrix in the degenerate subspace is $V_0 \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$.

A. 1 only B. 2 only C. 1 and 3 only D. 2 and 3 only E. All of the above.

QM2 Concept Test 11.7

For hydrogen atom, the Zeeman term in the perturbation is given by $H'_Z = \frac{e}{2m}\left(\vec{L} + 2\vec{S}\right) \cdot \vec{B}_{ext}$. Choose all of the following statements that are true about the intermediate field Zeeman effect, where neither the Zeeman term H'_Z nor the fine structure term H'_{fs} dominates.

1) The "good" basis states for the perturbation are the coupled states $\left|n, l, s, j, m_j\right\rangle$.
2) The "good" basis states for the perturbation are the uncoupled states $\left|n, l, m_l, s, m_s\right\rangle$.
3) Both the coupled and uncoupled states are equally "good" states for the perturbation.

A. 1 only B. 2 only C. 3 only D. Not enough information
E. None of the above