QM2 Concept Test 9.3

For non-degenerate perturbation theory, the first order correction to the nth stationary state $\psi_n{}^1$ can be written as a superposition of the unperturbed wavefunctions $\psi_m{}^0$. Choose all of the following statements that are correct.

1) $E_n{}^1 = \left\langle \psi_n{}^0 \middle| \hat{H}' \middle| \psi_n{}^0 \right\rangle$.

2) $\psi_n{}^1 = \sum_{m \neq n} c_m{}^{(n)} \psi_m{}^0$

3) $c_m{}^{(n)} = \frac{\left\langle \psi_m{}^0 \middle| \hat{H}' \middle| \psi_n{}^0 \right\rangle}{E_n{}^0 - E_m{}^0}$ for $m \neq n$.

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

QM2 Concept Test 9.4

The stationary states for a particle in a one dimensional infinite square well confined between $0 \leq x \leq a$ are $\psi_n(x) = A_n \sin\left(\frac{n\pi x}{a}\right)$. If a delta-function perturbation $\hat{H}' = \alpha\delta(x - \frac{a}{2})$ is placed at the center of the well, choose all of the following statements that are correct about the new system to first order in perturbation theory.

1) The ground state energy of the new system is the same as the ground state energy of the unperturbed system (1D infinite square well).
2) The first excited state energy of the new system is the same as the first excited state energy of the unperturbed system.
3) The first excited state wavefunction of the new system is the same as the first excited state wavefunction of the unperturbed system.

A. 1 only B. 2 only C. 3 only D. 2 and 3 only E. None of the above

QM2 Concept Test 10.3

A perturbation $\hat{H}'$ acts on a hydrogen atom with the unperturbed Hamiltonian $\hat{H}^0 = -\frac{\hbar^2}{2m}\nabla^2 - \frac{e^2}{4\pi\varepsilon_0}\frac{1}{r}$. To calculate the perturbative corrections, we use $|n, l, m_l, s, m_s\rangle$ (the eigenstates of ($\hat{H}^0$,$\hat{L}^2$, and $\hat{L}_z$) as the basis vectors. Choose all of the following statements that are correct.

1) If $\hat{H}' = \alpha\hat{L}_z$, where α is a suitable constant, we can calculate the first order corrections as $E^1 = \langle n, l, m_l, s, m_s|\hat{H}'|n, l, m_l, s, m_s\rangle$.
2) If $\hat{H}' = \alpha\delta(r)$, the first order correction to energy is $E^1 = \langle n, l, m_l, s, m_s|\hat{H}'|n, l, m_l, s, m_s\rangle$.
3) If $\hat{H}' = \alpha\hat{J}_z$ (z component of $\vec{J} = \vec{L} + \vec{S}$) we can calculate the first order correction as $E^1 = \langle n, l, m_l, s, m_s|\hat{H}'|n, l, m_l, s, m_s\rangle$.

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

QM2 Concept Test 10.4

A perturbation $\hat{H}'$ acts on a hydrogen atom with the unperturbed Hamiltonian $\hat{H}^0 = -\frac{\hbar^2}{2m}\nabla^2 - \frac{e^2}{4\pi\varepsilon_0}\frac{1}{r}$. To calculate the perturbative corrections, we use the coupled representation $\left|n, l, s, j, m_j\right\rangle$ as the basis vectors. Choose all of the following statements that are correct.

1) If $\hat{H}' = \alpha\hat{L}_z$, where α is a suitable constant, we can calculate the first order corrections as $E^1 = \langle n, l, s, j, m_j|\hat{H}'|n, l, s, j, m_j\rangle$.
2) If $\hat{H}' = \alpha\delta(r)$, the first order correction to energy is $E^1 = \langle n, l, s, j, m_j|\hat{H}'|n, l, s, j, m_j\rangle$.
3) If $\hat{H}' = \alpha\hat{J}_z$ (z component of $\vec{J} = \vec{L} + \vec{S}$) we can calculate the first order correction as $E^1 = \langle n, l, s, j, m_j|\hat{H}'|n, l, s, j, m_j\rangle$.

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

QM2 Concept Test 10.5

A perturbation $\widehat{H}'$ acts on a hydrogen atom with the unperturbed Hamiltonian $\widehat{H}^0 = -\frac{\hbar^2}{2m}\nabla^2 - \frac{e^2}{4\pi\varepsilon_0}\frac{1}{r}$. Choose all of the following statements that are correct.

1) If $\widehat{H}' = \alpha(\hat{L}_z + \hat{S}_z)$ we can calculate the first order correction as $E^1 = \langle n, l, s, j, m_j | \widehat{H}' | n, l, s, j, m_j \rangle$.
2) If $\widehat{H}' = \alpha(\hat{L}_z + \hat{S}_z/2)$ we can calculate the first order correction as $E^1 = \langle n, l, s, j, m_j | \widehat{H}' | n, l, s, j, m_j \rangle$.
3) If $\widehat{H}' = \alpha(\hat{L}_z + \hat{S}_z/2)$ we can calculate the first order correction as $E^1 = \langle n, l, m_l, s, m_s | \widehat{H}' | n, l, m_l, s, m_s \rangle$.

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

QM2 Concept Test 11.4

Choose all of the following statements that are correct about the spin-orbit coupling term $\hat{H}'_{SO} = \left(\frac{e^2}{8\pi\varepsilon_0}\right)\frac{1}{m^2c^2r^3}\vec{S}\cdot\vec{L}$ in the Hamiltonian of the hydrogen atom (including the fine structure correction).

1) $\hat{H}'_{SO}$ commutes with $\hat{L}_z$.
2) $\hat{H}'_{SO}$ commutes with $\hat{J}_z = \hat{L}_z + \hat{S}_z$
3) $\hat{H}'_{SO}$ commutes with $\hat{L}^2$.

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