1. Explain why the maximum excitation level of the wavefunction increases by +2 with each order in perturbation theory.

2. Prove that the leading contribution to the k-tuples CI operator has order $\lceil k/2 \rceil$ in perturbation theory.

3. Write down the CI energy and singles and doubles equations in terms of C_k operators. Identify the leading order of each term in perturbation theory with and without Brillouin's theorem.

4. Prove that CIS$\cdots m$ is correct to order $\lfloor m/2 \rfloor$ in the wavefunction and $2\lfloor m/2 \rfloor + 1$ in the energy.

5. Write down the CC energy and singles and doubles equations in terms of T_k operators. Identify the leading order of each term in perturbation theory with and without Brillouin's theorem.

6. Explain why the leading contribution to the k-tuples cluster operator has order $k-1$.

7. Prove that CCS$\cdots m$ is correct to order $m-1$ in the wavefunction and $m + \lfloor m/2 \rfloor$ in the energy.

8. "Derive" the [T] correction and evaluate it, showing both the diagrams and their algebraic interpretation.[1] [2] You may write your answer in terms of ${}^{[2]}t_{abc}^{ijk}$ amplitudes and evaluate those separately.

$$E_{[\mathrm{T}]} = \langle \Phi | T_2^\dagger V_\mathrm{c} T_3^{[2]} | \Phi \rangle \qquad\qquad T_3^{[2]} = (\tfrac{1}{3!})^2 \sum_{\substack{abc\\ijk}} \tilde{a}_{ijk}^{abc} \langle \Phi_{ijk}^{abc} | R_0 V_\mathrm{c} T_2 | \Phi \rangle \tag{1}$$

9. Prove that the left and right EOM-CC wave operators are given by

$$ {}^kR = \exp(-T)({}^kC_0 + {}^kC) \qquad\qquad {}^kL = ({}^kC_0 + {}^kC)^\dagger \exp(T) \tag{2}$$

where ${}^kC_0 + {}^kC$ is the CI wave operator for the k^{th} state. Use this to show that we can determine excited state expectation values and transition matrix elements for an observable W as $\langle \Psi_k | W | \Psi_k \rangle = \langle \Phi | L_k \overline{W} R_k | \Phi \rangle$ and $\langle \Psi_k | W | \Psi_l \rangle = \langle \Phi | L_k \overline{W} R_l | \Phi \rangle$ where $\overline{W} \equiv \exp(-T) W \exp(T)$.

10. Derive the CCD lambda equations.

11. Prove the Hellmann-Feynman and generalized Hellmann-Feynman theorems.

12. Derive the Löwdin functional.

13. Derive the $(m+1)_\Lambda$ correction from the coupled-cluster Löwdin functional.

14. "Derive" the (T) correction as an approximation to $(\mathrm{T})_\Lambda$ correction and evaluate it.

$$E_{(\mathrm{T})} = E_{[\mathrm{T}]} + \langle \Phi | T_1^\dagger V_\mathrm{c} T_3^{[2]} | \Phi \rangle \tag{3}$$

[1] "Derive" here means "give detailed motivation for".

[2] The operator Q_3 here simply projects onto the space of triply substituted determinants.