8.421: Pre-Class Questions February 12, 2020

1. Does the spin operator commute with the Zeeman Hamiltonian?
   
   - The Zeeman Hamiltonian is of the form $H = -\vec{\mu} \cdot \vec{B} = -\gamma \hat{S}_z \hat{B}_z$. Spin operators follow the commutator relations $[S_i, S_j] = \epsilon_{ijk} S_k$. Therefore, the general spin operator $\hat{S} = \hat{S}_x + \hat{S}_y + \hat{S}_z$ does not commute with $\hat{S}_z$.

2. What is the equation of motion that describes the time evolution of a quantized magnetic moment in an applied external magnetic field?
   
   - $\frac{d}{dt} \hat{\mu} = \gamma \hat{\mu} \times \vec{B}$

3. Does the equation of motion depend on the value of the spin?
   
   - No, it is valid for any spin. However, it is derived from a spin 1/2 system.

4. For spin $S = 1/2$ atoms in a time-dependent magnetic field, what is the Rabi frequency?
   
   - $\Omega_R = \gamma B_{\text{eff}} = \sqrt{(\gamma B_0 - \omega)^2 + \gamma^2 B_1^2}$

5. For a classical magnetic moment (which has the same equation of motion as the quantum spin): Can you give an example what can cause $T_1$ and $T_2$ relaxation processes?
   
   - damping due to collisions or fluctuations in the strength of the quantizing magnetic field $B_0$ causes $T_1$ decay, and/or the frequency of the driving magnetic field $B_1$ can cause $T_2$ decay.