8.421: Pre-Class Questions February 18th, 2020

1. What processes are not described by unitary evolution (i.e. the Schrödinger equation)?

- Unitary evolution refers to the notion that we are working with an entirely closed quantum system. For an open quantum system, processes of decoherence and dephasing are not accounted for in the Schrödinger equation. For such processes we need to expand the Schrödinger equation with a Lindblad operator. However, there are ways we can simplify such process to account for non-unitary evolution.

2. When and how can we add losses to a wavefunction description?

- Adding a decay mechanism by extending the equation of motion to

$$\dot{\rho} = \frac{1}{i\hbar}[H, \rho] - \left(\rho - \rho^T\right)/T_e$$

Where T_e is the time constant for the system to reach thermal equilibrium ρ^T.

3. What are the two types of elements in a density matrix?

- Population (diagonal elements) and Coherences (off-diagonal elements)

4. Given some observable $\hat{A}$, what is the expectation value of $\hat{A}$ for density matrix of a two level system ρ?

- $\langle\hat{A}\rangle = \mathrm{Tr}(\rho\hat{A})$

5. How can we check whether a density matrix comes from a pure state or a mixed state?

- $\mathrm{Tr}\left(\rho^2\right) \leq 1$, with equality only for a pure state.

6. What are the two relaxation times in a quantum system approaching thermal equilibrium? Describe them.

- T1 - decay time for population differences between non-degenerate levels, e.g. for r_3 (also called the energy decay time).
- T2 is the dephasing time. As the system evolves, dephasing terms lead to the decay of the coherences in the density matrix (between either degenerate or non-degenerate states). Which lead to a classical statistical mixture of different populations across all levels.

  Note : In general, it requires a weaker interaction to destroy coherence (the relative phase of the coefficients of different states) than to destroy the population difference, so some relaxation processes will relax only the phase, resulting in $T_2 < T_1$. (caution: certain types of collisions violate this generality.)

7. 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?

- T_1 : Intensity fluctuations in our bias field $B_0\,\hat{z}$
- T_2 : Frequency fluctuations in our microwave field $B_1\,(\omega)\,\hat{x}$.