Before-class Questions #10:

Q1: We are interested in the interaction of a (two-level) atom with light. What is the frequency scale separating the width of narrowband spectral distributions from broadband spectral distributions?
A1: $\Gamma$, the natural linewidth/inverse decay rate of the excited state.

Q2: What restrictions must we impose to describe atom-light interactions (specifically, Rabi oscillations of the state of a two-level atom due to a monochromatic field) and neglecting spontaneous emission?
A2: Since the effects of spontaneous emission will only become apparent at times $t \sim (\Gamma)^{-1}$, we restrict ourselves to times $t < (\Gamma)^{-1}$. If we want to observe full Rabi cycles, this requires strong driving fields, i.e. we need a large Rabi frequency $\omega_R \gg \Gamma$.

Q3: How does the probability of a two-level atom being driven to the excited state scale with time $t$ for $t \ll (\delta)^{-1} = (\omega - \omega_0)^{-1}$?
A3: $P \sim t^2$, for both monochromatic and broadband light.

Q4: Which two effects in the two-level atom is not accounted for by perturbation theory?
A4: Power broadening. The generalized Rabi frequency in the perturbative regime is $\Omega_R = (\omega_R^2 + \Delta^2)^{1/2} \approx \Delta$, and depletion of the initial state.

Q5. What process is responsible for thermal equilibrium in a system of light and two-level atoms? What would a simple rate argument tell you about the ratio of excited to ground states ($N_e/N_g = ?$) if we had only the Einstein B coefficients? Compare with the result you would expect for $N_e/N_g$ for two-level atoms in thermal equilibrium (ignore degeneracy).
A5: Spontaneous emission. If spontaneous emission did not exist, a simple rate argument would give the result $N_e/N_g = 1$ (reached asymptotically for long times). For a two-level atom in thermal equilibrium, $N_e/N_g = \text{Exp}\left[-\frac{\hbar \omega_{eg}}{kT}\right]$ (the Boltzmann factor).