Example Section II (5 mark) questions

1. For a coherent state, if the probability of detecting exactly one photon is P_1, and that of detecting more than one photon is $P_{>1}$, then what is the intensity ($|\alpha|^2$) of the coherent state?

2. Consider a non-interacting gas of N identical two-level atoms interacting with a bath of broadband thermal light.

   (a) Write down rate equations for the populations N_g and N_e for the atoms in the ground and excited states, describing all spontaneous and stimulated processes. (You may assume that the ground and excited atomic states are each non-degenerate.) [1 mark]

   (b) Assuming that the atoms are initially all in the ground state, explain when population inversion can occur in this system (e.g. using trial solution $N_g = C + D\exp(-Et)$). [4 marks]

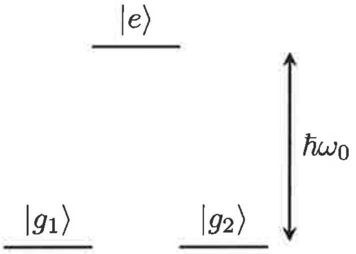
Example Section III (10 mark) questions

1. (a) Compute the second order coherence function for a one mode squeezed vacuum state. [7 marks]

   (b) As the squeezing parameter goes to infinity, is the light bunched, anti-bunched, or otherwise? [2 marks]

   (c) Might it be useful as a single photon source? [1 mark]

2. Starting with the system given by the energy level diagram



   (a) Under what conditions is the dipole approximation valid?

   (b) Derive the Hamiltonian in the presence of a field oscillating at frequency ω, in the rotating frame. Hint: before we used

$$R_z(\omega t) = e^{-i\omega\sigma_Z/2} \quad \text{with} \quad \sigma_Z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \tag{1}$$

   while now you'll want to use

$$\sigma_Z = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{bmatrix}. \tag{2}$$

   And to save you some calculation, I'll add:

$$R_z(\theta) = \begin{bmatrix} e^{i\theta/2} & 0 & 0 \\ 0 & e^{-i\theta/2} & 0 \\ 0 & 0 & e^{-i\theta/2} \end{bmatrix} \tag{3}$$

   (c) Use the RWA to derive the time-independent Hamiltonian, showing all steps and justifying all approximations.