Physics 482-01 and 690-01: Quantum Optics & Atomics
Due Date: Thursday, April 4, 2024.

Problem Set #6: Spontaneous Emission

1. Calculate the average excited state population as a function of time for an ensemble of 2-level atoms which are all in the ground state at $t \leq 0$, but for which there is an excitation laser that turns on for $t > 0$ with an intensity that corresponds to a Rabi frequency $\Omega = \gamma$, where $1/\gamma$ is the excited state population lifetime. The laser has a detuning of $\delta = \gamma$.

Your calculation can be analytical or numerical (you may use any mathematical package or programming language if this proves helpful, i.e. Maple, Mathematica, MatLab, Python, Excel, C/C++, VisualBasic, Java, Fortran, etc….). Present your answer in the form of a computer-generated plot showing the average excited state population versus time over the range t=0 to $t=10/\gamma$. You may use the **density matrix formalism** or the **quantum Monte Carlo method** – in the case of the quantum Monte Carlo method, only 20 averages are necessary (though if you write a program it is easy to make the number of averages much larger). Please submit all program code.

2. Explain and derive the second line of equation 3a in the paper:

J. Dalibard, Y. Castin, and K. Mølmer, "Wave-Function Approach to Dissipative Processes in Quantum Optics", *Phys. Rev. Lett.* **68**, 580 (1992).

Furthermore, provide the intermediate steps that lead to equations 4 and 5, i.e. provide a detailed derivation of these equations from the Monte Carlo wavefunction method from the definition of $\sigma(t)$ given in the paper.

Extra Graduate Student Problem

3. Solve problem 1 using the other solution method.