Homework Assignment #7

1) 7.5
2) 7.6
3) 7.14
4) Determine the behavior of a 4-level laser starting from when it is pumped until it reaches steady state. (This problem has extra weight - worth 25 points.) See below for detail.

The gain medium has these properties: $\tau_2 = 30\ \mu s$, $\sigma_{12} = 3.0 \times 10^{-19}\ cm^2$, $\Delta E_{12} = 1.24$ eV, l = 10 cm and D = 4.0 mm (upper state lifetime, transition cross-section, transition energy, medium length and medium diameter respectively).

The cavity is described by: $L_{opt} = 100$ cm, $R_2 = 95\%$ and $L_i = 3.0\%$ (optical path length, output coupler and internal loss respectively).

Assume a stable cavity and constant pumping at 5 times threshold. For simplicity, also assume that the laser mode has a uniform cross-section with the same diameter as the gain medium.

(a) Present your results using two well-labeled graphs. The first should plot the population inversion and number of cavity photons from start until steady state is reached. The second should plot the same quantities, but as an expanded view of the first relaxation oscillation. Include a terse description of your numerical integration technique, just as you did in the previous homework assignment.

(b) I can think of three possibly important time scales in the problem: the round-trip travel time, the cavity lifetime and the upper-state lifetime. Are there any features in the above graphs that can be associated, even if roughly, with these time scales?

(c) Compare your numerical results for the steady state inversion and photon number to the predicted values. *These must agree within 1% for full credit.*

(d) What is the output power of this laser? If the gain medium is pumped with perfect coupling and absorption efficiency using an 800 nm diode-bar laser, what pump power is required?

(e) Keeping the same numerical value for the pump rate as used for the above, what would be the output power of this laser if its output coupling had been chosen correctly?

Suggestions: As discussed in class and described in the text, you should expect spikes in the output occurring over a long time scale. This can be a challenging combination for numerical analysis. Select your time step accordingly. (Question: What is the correct time scale to use when picking your initial time step? Answer: Look at the equations of motion!) Assume that spontaneous emission guarantees that there is at least one photon in the correct mode - don't allow the photon number to drop below one. Finally, this assignment differs from the previous one in that you must integrate two coupled equations at the same time: one for ϕ and one for N. The procedure is the same, however. For example, in the "quick and dirty" approach described earlier, you would: evaluate the derivatives $d\phi/dt$ and dN/dt, use the derivatives to update the values of ϕ and N and repeat as needed.