Laser Physics PHGN480
Midterm - take home: due thursday Nov 6 in class.
Ground rules: open book, open notes. No discussion with others - ask me if you need clarification. You may use *Mathematica.*

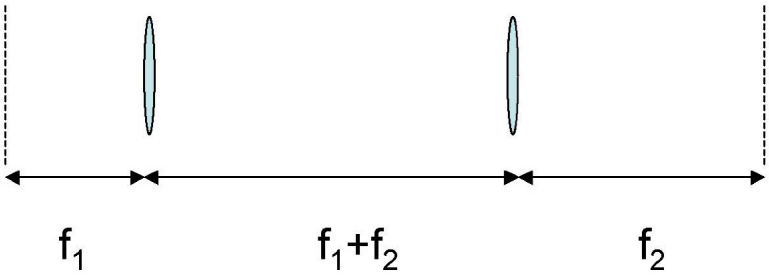
- **problem 1**
  Two level system in saturation.
  Consider an atomic system: the population difference is $\Delta N = N_1 - N_2$ and the total atomic density is $N_t = N_1 + N_2$. At t = 0, there is an initial value of $\Delta N(0)$, and an constant-intensity incident beam is turned on that has a frequency that is resonant with the energy difference. Use rate equations to calculate the evolution of the population difference $\Delta N(t)$. Express your result in terms of the saturation intensity. Show all your work.
  Comments:
  - in your rate equations, include spontaneous emission with a rate A.
  - you may assume that the two states have the same level of degeneracy ($g_1 = g_2$).

- **problem 2**
  Consider a molecule that makes a transition between two rotational levels J' and J'', while at the same time the vibrational level changes from v' to v'' (the electronic level stay the same).

  - **a) Calculate an expression for the dipole moment for a dipole transition from the v'=1, J' = 3 to the v''=0, J'' = 2 levels. You may assume the molecule starts and ends in the $J_z = 0$ sublevel for the purposes of this integral. Note that the wavefunction for the molecule is the product of a spherical harmonic with a constant value of R (for the rotational state), and the simple harmonic wavefunction. For the SHO portion of this problem, you may adapt the calculation shown in Griffiths, example 9.1.**

  - **b) The molecular radius is R = 2.66 angstroms, the atomic mass is 127 atomic mass units, and the moment of inertia is $I = m R^2 / 2$. The vibrational frequency is 6.43×10^{12} Hz.**
    - Calculate the energy difference between these levels in eV and the corresponding wavelength for the transition.
    - Although there can be transitions among other J_z sublevels (all degenerate in energy), with slightly differing dipole moments, let's assume the dipole moment you calculated in part a works for all of them. Calculate the spontaneous emission rate for the transition between the levels in part a.

- **problem 3**
  Consider the propagation of a beam through a simple imaging system consisting of two lenses of focal lengths f_1 and f_2, separated by a distance $f_1 + f_2$. The starting plane is a distance f_1 at the left, and the final plane is a distance f_2 from the second lens.



- **a) Write the ABCD matrix for this system.**
- **b) Interpret this system geometrically: what happens to a ray of input height h, and ray angle h'?**
- **c) Interprete the effect of this system on a Gaussian beam:**
  - How is the output waist and beam radius affected? Consider both cases where:
  > the beam is at a waist at the input, and
  > the beam is not at a waist at the input
- **d) if plane mirrors are placed at the object and image distances to form a resonator, what will be the value of the stability parameter?**
  > Will the cavity be stable, marginally stable, or unstable? Based on the stability parameter, make a sketch of an equivalent two-mirror cavity (i.e. two curved mirrors, no flat mirrors).