PHYS 404 and 690-03
Problem Set due on day, Friday, April 6, 2012.

Problem Set #6
Laser Cooling and Trapping

1. Thermal contact between a MOT and environment

Consider a ^{87}Rb magneto-optical trap (MOT) that is formed inside a vacuum chamber at room temperature (T = 300 K). You may assume a perfect vacuum. You should assume that ^{87}Rb is a perfect 2-level atom with linewidth of $\gamma = 2\pi \times 6$ MHz on the D2 line at 780.24 nm. You shine a flashlight that directs 10 W of optical power (collimated to diameter of 1 m) onto the trapped ^{87}Rb atoms in the MOT.

Make an estimate of the optical bandwidth (make sure that 780.24 nm is included) of the flashlight and calculate the scattering rate of flashlight light photons off of a single trapped ^{87}Rb atom.

What is the heating rate of the atom due to the flashlight?

2. Repumping in a MOT

Consider an ^{87}Rb MOT produced by 6 beams each with a diameter of 5 cm and with a power of 3 mW per beam. The trapping lasers are all detuned 25 MHz to the red of the D2 cycling transition ($5S_{1/2}$, F=2 $\leftrightarrow$ $5P_{3/2}$, F'=3). We will neglect the effect of the magnetic field of the MOT, and assume that all atoms are optically pumped so that they behave as 2-level atoms. Calculate the total scattering rate of an atom in the MOT in the limit $I \ll I_{sat}$. Occasionally, the atom will undergo a transition to the $5P_{3/2}$, F'=2 level. Estimate the scattering rate for the transition $5S_{1/2}$, F=2 $\leftrightarrow$ $5P_{3/2}$, F'=2 using the 2-level atom formalism. At what rate are atoms depumped into the $5S_{1/2}$, F=1 level? You will need to consult the week 7 overheads on hyperfine structure of ^{87}Rb and branching ratios.

You can repump the atoms to the $5S_{1/2}$, F=2 level by applying a second laser. Indicate which transition this laser should target and the minimum intensity it will have to have in order to adequately repump the atoms.