Physics 462 Homework # 8 Spring 2008

Due: Friday, April 18

1) Problem 9.12, Griffiths

2) (similar to 9.14) An electron in the $n = 4$, $l = 1$, $m = 0$ state of hydrogen decays by a sequence of (electric dipole) transitions to the ground state.
   a. What decay routes *to the ground state* are open to it? Specify them in the following way (for the purposes of this problem let us consider Bohr hydrogen):

$$|410\rangle \rightarrow |nlm\rangle \rightarrow \cdots \rightarrow |100\rangle$$

   b. If you had a bottle full of atoms in this state, assuming that each transition has equal probability, what fraction of them would decay via each route having unique values of l (that is, sum over m)? [Hint: Each transition with a unique Δl , Δm combination is considered a different transition. Why do we care? Because this sort of summing governs the relative intensity of different spectral lines. Since atoms are degenerate in m (unless a B-field is applied), spectral line intensities depend on the m-degeneracy of the initial and final states.]

3) Each scattering event of visible light changes the speed of an atom by a "few" cm/s. Calculate how much is a "few" for the Rb $5^2S \rightarrow 5^2P$, 781 nm transition (τ = 26.6 ns). For Rb atoms coming from a source heated to a temperature of 200 C, what is the average thermal speed v_T of the atoms? How many scattering events are required to stop atoms with this average speed? Suppose such a slowing experiment is done with a laser tuned to frequency $\omega_l = \omega_{atom} - kv_T$ to compensate for the Doppler shift. How many scattering events will occur before such an atom is slowed enough to be Doppler shifted out of resonance with the laser?

4) There are several methods to compensate for the changing Doppler shift during the slowing of atoms, including laser sweep, Zeeman tuning, broadband light and so on. Derive the formula

$$B = B_0\sqrt{1 - \frac{z}{z_0}}$$

to describe the spatial dependence of the magnetic field (as I did in class). [$B_0 = \frac{3}{2}\frac{\hbar k v_0}{\mu_B \Delta M_J}$ and $z_0 = \frac{M v_0^2}{\eta \hbar k \Gamma}$, where v_0 is the initial velocity.] Calculate the magnetic force $\vec{F} = \mu\nabla|\vec{B}|$ in this field, and compare it to the maximum optical force $\hbar k\Gamma / 2$.