PHY 3107, Spring 2016, Homework #5

due Thursday, Feb. 26, at 9:30 am (beginning of class)

1.) An electron in the hydrogen atom in the *n=2* state absorbs a photon and is excited to the *n=4* state. A) What is the photon wavelength for this transition? B) Subsequently, the atom will "decay" or drop to lower energy states by emitting 1, 2, or 3 photons. What are the possible wavelengths of the emitted photons?

2.) A decent fraction of the class had difficulty with this on the exam: An electron in the hydrogen atom is in the state *n*=2, *l*=1. A) Find the average radius, <*r*>. [Hint: here you use an integral.] B) Find the most probable value of the radius. [Hint: here you take a derivative.]

3.) The normal Zeeman effect consists of the splitting of a spectral line into multiple components. Since m_l can have *2l+1* substates (differing in energy by $\mu_B B$ if the atom is in an external magnetic field *B*), many states are possible. However if we look at transitions between states the photon carries off angular momentum $l = \hbar$. A) Given that, what are the possible changes in m_l for an atom in an external magnetic field? B) If a sample of a certain element is put in a 0.300 T magnetic field and excited, find the distance $d\lambda$ (in nm) between the Zeeman components of the 450 nm spectral line. [Hint: $\nu = c/\lambda$ but you will need to take a derivative to find $d\nu$.]

4.) In the Stern-Gerlach experiment, a non-uniform magnetic field was used. Since $U = -\vec{\mu} \cdot \vec{B}$, and the force is the negative gradient of the potential energy we can write $\vec{F} = -\nabla\left(-\vec{\mu} \cdot \vec{B}\right) = \mu_z \frac{\partial B}{\partial z} \hat{z}$ for an external magnetic field in the *z*-direction. Determine the acceleration of a hydrogen atom (in the ground state) in a magnetic field which has a rate of change of 10 T/m. [Hint: although the force is on the electron's magnetic moment, the entire atom accelerates.]

5.) In the previous problem about the Stern-Gerlach experiment, how much would a hydrogen atom emanating from a 800K oven (kinetic energy, $K = \frac{3}{2} k_B T$) be deflected in travelling 1 m along the z-axis (e.g., through the magnetic field which has a rate of change of 10 T/m)?

6.) Example 9.4 in the textbook shows that the spin-orbit energy splitting between the $3P_{3/2}$ and the $3P_{1/2}$ state in Sodium is 2.13×10^{-3} eV. This energy difference corresponds to one state being raised in potential energy by $+\mu_B B$ and the other state being lowered in the potential energy by the amount $-\mu_B B$. Find the magnitude of the magnetic field at the site of the orbiting *3p* electron in sodium.