PHY 3107, Spring 2018, Homework #4

due Friday, Feb. 16

1.) 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 $\boldsymbol{B}_{\text{ext}}$), many states are possible. However, if we look at transitions between states the photon carries off one unit of angular momentum $\Delta l = \hbar$. A) Given that, what are the possible changes in m_l for an atom in an external magnetic field? B) If a sample is placed in a 0.500 T magnetic field and excited, find the possible Zeeman energies (i.e., the energies due only to the external magnetic field). C) Now find the distance, $d\lambda$, (in nm) between these Zeeman components of the 450 nm spectral line. [Hint: $E = h\nu$, and $\nu = c/\lambda$ but you will need to take a derivative of the energy to find $d\lambda$.]

2.) 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 $\vec{F} = -\nabla(-\vec{\mu} \cdot \vec{B}) = \mu_z \frac{\partial B}{\partial z} \hat{z}$ 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 12 T/m. [Hint: although the force is on the electron's magnetic moment, the entire atom accelerates.]

3.) In the previous problem about the Stern-Gerlach experiment, how much would a hydrogen atom emanating from a 700 K 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 12 T/m)?

4.) 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.