1. Photon beam from a certain direction $\mathbf{k}$ falls on a hydrogen atom in its ground state 1s.

   a) Calculate the absorption rate (probability of absorption per unit time) for a particular transition of the atom to the $2p$ excited state with $m = 0$. First assume that the photons are polarized and calculate the dependence of the rate on the polarization and the falling angles.

   b) Then assume that the polarization was not specified. What is the angular dependence in this case? Help: not knowing the photon polarization means that there is equal probability of its different polarizations.

   c) Indicate what will you have to change in the above treatment if instead of $2p$ excited state you'd need to find the absorption rate to the $3d$ state. Don'd do the detailed calculations but indicate what will you need to calculate.

2. This problem draws heavily on Berry's original paper and lecture notes. Consider the two level Hamiltonian

$$H = \lambda(q\sigma_x + p\sigma_y) + \varepsilon\sigma_z \quad ,$$

   where $\sigma_{x,y,z}$ are Pauli matrices.

   - By treating q and p as parameters calculate the adiabatic energies as functions of these two parameters. Plot them schematically for $\epsilon > 0$, < 0 and $= 0$.
   - Consider the conditions of the above levels to cross. Does this happen on a surface, a line, a point in the parameter space of this model Hamiltonian? (For those curious) - how does this compare with what is discussed in the lecture notes about the levels crossings?
   - Calculate the Berry connections (the "vector potential") $\bar{A}(p, q) \equiv (A_q, A_p))$ in the space of the two parameters p and q (Help: choose just one of the adiabatic states)

- (For extra credit - consult the lecture notes). Calculate the Berry curvature (the "magnetic field") $F_{pq}(p,q) = \partial_q A_p - \partial_p A_q$ where ∂_a is a short hand for $\partial/\partial\alpha$.

  Note that the H has the form $\vec{d} \cdot \vec{\sigma}$ with the 3D vector $\vec{d} = (\lambda p, \lambda q, \epsilon)$. In this notation F_{pq} can be written as

  $$F_{pq} = \frac{\vec{d} \cdot [\partial_p \vec{d} \times \partial_q \vec{d}]}{2|\vec{d}|^3},$$

- (not for credit - just for you) What is the "source" of this "magnetic field"?