PHYS 452: Quantum Mechanics II - Fall 2016
Homework #3, due Tuesday September 27 in class

Perturbation theory, fine and hyperfine structure

1. Consider a free electron in a magnetic field that is a combination of two uniform magnetic fields. The first one is along the z-direction, $\mathbf{B}_1 = (0, 0, B_z)$. The second one is along the x-direction, $\mathbf{B}_2 = (B_x, 0, 0)$.

   (a) Assuming $B_x \ll B_z$ use the perturbation theory to find the energies and eigenstates up to the first non-vanishing order.

   (b) Solve the problem exactly and see if the perturbative solution in the previous part reproduces the exact solution when $B_x \ll B_z$.

2. Problem 6.23 in Griffiths.

3. Problem 6.40a (part b is not required) in Griffiths.

4. Problem 6.29 in Griffiths. In addition, consider the muonic hydrogen in exactly the same manner as the usual hydrogen (the muonic hydrogen is a hydrogen atom in which the electron is replaced by a much heavier muon). How does the correction due to the finite size of the nucleus in muonic hydrogen compare to fine and and hyperfine structure?
   Side note: knowing the energy levels from the experiment one can, in principle, determine the radius of the proton (parameter b in the above problem). One of the recent and still unresolved puzzles of modern physics comes from the fact that the proton radius obtained in experiments with muonic hydrogen differs somewhat from the "official" value obtained in electron-proton scattering experiments. This puzzle has been named "the proton radius puzzle".