Problem Set 8

In this homework, we're going to practice working with rotations and angular momentum operators.

Question 1 Do the Webwork questions on spin and angular momentum for Tuesday.

Question 2 For Tuesday: read the "Addition of Angular Momentum" section of the "Notes on Rotations", and section 6.3 (7.3 in new edition), "The fine structure of hydrogen".

Question 3 For Thursday: Read Griffiths chapters 6.4 (Zeeman effect) and 6.5 (hyperfine splitting), and problem 6.36 (Stark effect), ideally before this Thursday's class. For each of the following, make sure you understand the physical origin of the effect, the specific perturbation to the Hamiltonian that we need to take into account the effect, and whether the perturbation is something we can control or whether it is a small effect already present.

a) The Zeeman effect

b) The Stark effect

c) The hyperfine splitting

Question 4 (hand in Thursday) A spin 1 particle system has a Hamiltonian $H_0 = QJ_z^2$. If we add a Hamiltonian perturbation $H_1 = \lambda(J_x^2 - J_y^2)$, determine all of the energy eigenvalues of the system up to first order in λ using perturbation theory. *Hint: you can rewrite J_x and J_y in terms of J_+ and J_-.*

EXTRA: Can you determine the exact energies?

Question 5 (hand in Thursday) Suppose we have the state $|n = 2, l = 1, m = 1\rangle \otimes |s_z = 1/2\rangle$ for a hydrogen atom. If we rotate the state by angle ϵ around the x axis (right-handed-rotation), what is the change in the state to first order in ϵ?

EXTRA: Can you determine what state we would get after a $\pi/6$ rotation about the x-axis?