BirZeit University
Faculty of Science-Department of Physics
Quantum Mechanics Phys635
Spring 2016
Second Exam, May. 5th 2016

1. Write xy, as components of a spherical (irreducible) tensor of rank 2. Evaluate

$$e < \alpha, j, m' | xy | \alpha, j, m >$$

2. We are to add angular momenta $j_1 = 1$ and $j_2 = 1$ to form j =2,1, and 0 states. Using either the ladder operator method or the recursion relation, express all nine $|jm>$ eigenkets in terms of $|j_1 m_1 j_2 m_2>$.

3. A beam of excited hydrogen atoms in the 2s state passes between the plates of a capacitor in which a uniform electric field E exists over a distance L. The hydrogen atoms have velocity v along the x-axis and the E field is directed along the z-axis. All the n = 2 states of hydrogen are degenerate in the absence of the E field, but certain of them mix when the field is present.
   (a) Which of the n = 2 states are connected in first order via the perturbation?
   (b) Find the linear combination of n = 2 states which removes the degeneracy as much as possible.
   (c) For a system which starts out in the 2s state at t = 0, express the wave function at time t $\leq \frac{L}{v}$.
   (d) Find the probability that the emergent beam contains hydrogen in the various n = 2 states.

4. A spin-$\frac{1}{2}$ particle of mass m moves in spherical harmonic oscillator potential $V = \frac{1}{2} m\omega^2 r^2$ and is subject to an interaction $\lambda \sigma \cdot r$. The net Hamiltonian is therefore:

$$H = H_0 + H_1$$
$$H_0 = \frac{P^2}{2m} + \frac{1}{2} m\omega^2 r^2$$
$$H_1 = \lambda \sigma \cdot r$$

   (a) What is the shift in energy for the ground state through first order in perturbation H_1.
   (b) Compute the shift of the ground state energy through second order in the perturbation H_1.