Physics 135c
H. W. Assignment 1

1.) Determine the order of energy levels for a *very deep* ($V_0 >> \hbar^2/ma^2$ for $r > a$ and $V_0 = 0$ for $r \leq a$) 3-dimensional potential. Draw an energy level diagram for the first 10 discrete levels, with the spacing between levels scaled according to the energy differences. Label the levels with the principal quantum number and the angular momentum of the state, using the notation where s, p, d, f, g, h,... corresponds to $l =$ 0,1,2,3,4,5... (eg. $1s$ for $n = 1, l = 0$ and $4f$ for $n = 4, l = 3$).
Do the same calculation and draw a similar energy level diagram for the first 5 discrete energy levels for a 3-dimensional harmonic oscillator potential ($V = m\omega^2 r^2/2$).
In each case be sure to indicate any degeneracies, and include the number of identical fermions that can be placed in each level.

2.) Consider the following spin wave function for a particle with spin 1/2:

$$\phi_{spin} = a\chi_+ + b\chi_-,$$

where χ_+, χ_- are eigenstates of $\hat{s}_z$ (eg. $\hat{s}_z\chi_+ = \frac{1}{2}\chi_+$ and $\hat{s}_z\chi_- = -\frac{1}{2}\chi_-$). Determine the relation between the coefficients a and b and the "direction" of the particle's spin given by the spherical coordinates θ and ϕ.

3.) Construct all possible spin wave functions $|JM>$ obtained from adding three spin 1/2 particles. Your final wave functions should be expressed in terms of $|m_1 m_2 m_3>$ basis states using the notation

$$|m_1 m_2 m_3> = |\uparrow\uparrow\downarrow>, |\downarrow\uparrow\downarrow>, ...$$

Comment on the symmetry of these states under the particle exchange operator.

4.) Bertulani Problem 1.6 (Chap. 1, Prob. 6)

5.) Given that $J^\pi = 1^+$ for the deuteron, that the pion has spin zero, and that the reaction

$$\pi^- + d \rightarrow n + n$$

can be observed when the π^- is captured at rest, determine the parity of the π^-.