Phys 761
Quantum Mechanics
Problem Set # 1

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1. Show that $[\hat{H}, \hat{L}_z] = 0$ and $[\hat{H}, \hat{L}^2] = 0$, where $\hat{H} = \hat{p}^2/2m + V(r)$

2. The wavefunction of an electron in the Hydrogen atom is given by $\psi(r, \theta, \phi) = -B(x + iy) \exp(-r/2a_0)$, where B is a real constant and a_0 is the Bhor radius.

   (a) Write down $\psi(r, \theta, \phi)$ in terms of $R_{nl}(r)$ and $Y_{l,m}(\theta, \phi)$ and find the values of the quantum numbers n, l, m

   (b) Find the constant B that makes the state $\psi(r, \theta, \phi)$ normalized

   (c) Find the mean value of r in this state

   (d) Find the most probable value of r in this state

3. Consider an electron in the Hydrogen atom that is being represented by the following mixed state

$$\Psi(r, \theta, \phi) = 2\psi_{1,0,0} + \psi_{2,1,0}$$

   (a) Normalize the wavefunction

   (b) What is the probability of finding the electron in the state $n = 3$

   (c) What are the possible results of individual measurements of energy, angular momentum, and the z-component of angular momentum

   (d) What are the probabilities of the possible results of individual measurements of energy, angular momentum, and the z-component of angular momentum

4. Consider a particle of mass m in a three dimensional delta function potential well given by

$$V(r) = -g\delta(r - a)$$

   where g is a constant. What is the range of values of the constant g that support a bound state.
   hint: take $l = 0$

5. Work out the schrodinger equation in polar coordinates ρ and ϕ, with $x = \rho\cos\phi$, $y = \rho\sin\phi$ for a potential that depends only on ρ. If the solution of the equation $\Psi(\rho, \phi)$ is written as $R(\rho)\Phi(\phi)$, what is the equation obeyed by $\Phi(\phi)$. What is the equation for $R(\rho)$.

Good Luck