

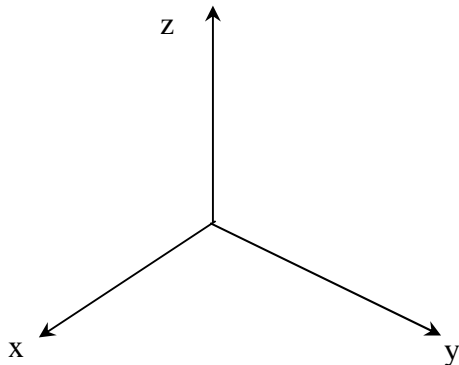
Part 1. Answer 6 of the following 7 questions. If you answer more than 6 cross out the one you wish not to be graded, otherwise only the first 6 will be graded. 10 points each.

1. Name two types of motion that have a zero-point energy.

2. What is the name and functional form of the potential energy for the electron in a hydrogen atom?

3. What is the magnitude of the orbital angular momentum of a 3d electron? Give the numbers of angular and radial nodes for the 3d orbital.

4. Draw a scale vector diagram to represent the states: $l = 1, m_l = -1, 0, 1$.



5. The p-orbital of an atom has two lobes of opposite phase separated by a node. One common question for students in General Chemistry is: "how does the electron get from one lobe to the other?" How do you answer this question?

6. Use the kinetic energy operator to calculate the kinetic energy of a particle on a ring (2D-rigid rotor) that has the wave function $e^{-2i\phi}$.

7. Normalize the ground state wave function for the hydrogen atom: $N e^{-\frac{Zr}{a_0}}$. Just set up the problem, don't work it through to a final answer. But, do include all important information that you would need to complete the problem and do the angular integrals (i.e. over θ and ϕ).

Part 2. Answer 3 of the following 4 questions. If you answer more than 3, cross out the one you wish not to be graded, otherwise only the first 3 will be graded. 14 points each.

8. Calculate the expectation value of the linear momentum of a harmonic oscillator with wave function $N e^{-\alpha^2 x^2}$.

9. Determine the commutator of the operators $\frac{d}{dx}$ and x .

10. What is the value of r at the radial node of the 2s orbital of the hydrogen atom? (Show your work)

11. The first excited state of a particle in a 1D-box is $\Psi = N \sin\left(\frac{2\pi x}{a}\right)$. Show that this wave function is an eigenfunction of the Hamiltonian for the particle in a box.

Extra Credit: 10 points. Finish the integral in Problem 7.