

Example Questions for Exam #3 PHY361

- The exam will cover sections 7-1 to 7-8, section 8-1 except heat capacities, 8-2, 8-3, 8-4 photon gas only, 8-5.
- Review end of section questions in text; chapter 7 homework, chapter 8 problems: 1, 2, 3, 4, 21.
- Be able to normalize wave functions show they are a solution to Schrödinger's equation, and perform basic separations of variables.

- Catalog variations of Schrödinger equation that can be solved by separation of variables.
- What is the Zeeman effect?
- How is the Pauli exclusion principle explained in terms of multi-particle wave functions?
- Examples of: bosons, fermions.
- Be able to plot f_B , f_{BE} , f_{FD} .
- Explain the properties of HeII. (Clarification: that's superfluid helium)
- What is a BEC? How is it different than other gasses?
- Explain three parts of Planck's formula in terms $f(E)$, $g(E)$, etc.
- Explain the wave-particle duality in terms the two different principles used to derive Planks law.
- What is the Fermi energy of a Na atom?
- In the 1-d dimensional model of a nucleus as N identical particles in an infinite square well of width $N*L$ where $L=1$ fm, write down a formula for the E_n , and p_n . What are the Fermi energy and momentum? Does it increase or decrease, as L gets smaller?
- Draw $f_{FD}(E)$ at $T=0$, and $kT=E_F/4$. Label the excited states and 'holes' in the latter case.
- Label the Maxwell distribution in terms of $n=g*f$.
- What are the differences between bosons and fermions: a) in wave function symmetry b) $f(E)$, c) physical properties? d) Show the features of $f(E)$ in each case that give rise to these properties?
- How is $f(E)$ normalized?
- Why is the transition temperature (T_c) between HeI and HeII called the 'lambda point'?
- Why does the liquid immediately stop bubbling after the transition? Does it stop boiling?
- Explain how statistics give rise to an outward pressure (strictly quantum mechanical) in a F-D gas?
- Calculate the fraction of excited $n=2$ states in a H atom on the surface of the sun $T=5800K$?
- Why cannot all three components of angular momentum be quantized?
- If the magnitude of L and two components were quantized, how could you derive the third? Thus, only the magnitude and one component can be quantized (to quantum numbers: l and m).
- Why is ' l ' called space quantization and ' m ' the magnetic quantum number?
- What is the minimum angle of L from the z -axis if $l=5$?
- Why are states with $E>0$ not quantized in the H atom? Describe the nature of these states.
- Draw the potential including the effective potential of the electron in an H atom for $l=0$ and $l=1$. On each, draw the graphical solutions of lowest energy: R_{10} , R_{20} ; R_{21} , R_{31} . Why is there not a R_{11} ? How many nodes does each function have? Hint: treat the potential for each value of ' l ' as a separate problem. Which has the largest value of $\langle r \rangle$?
- In three dimensions, shade in the regions of highest probability for the s , p_x , p_y , p_z , $d_{x^2-y^2}$, d_{xy} , d_{xz} , d_{yz} , $d_{3z^2-r^2}$ orbitals.
- Show how $Y_{11} \sim \sin \theta e^{i\phi}$ and $Y_{10} \sim \cos \theta$ are related to the p_x , p_y , and p_z orbitals.
- Show that for a symmetric potential $V(r)$ that L is conserved.
- Why is the 4s orbital filled before the 3d orbital in the periodic table?

- What is the spectroscopic notation for the $n=3, l=2, j=3/2$ state? What is the degeneracy of this state? Same for the $n=5, l=3, j=3/2$ state? What's wrong with this question?
- Know the observable consequences of intrinsic spin angular momentum. Why can't it be explained as an orbital effect?
- For $l=3, s=1/2$, what are the possible states (m_l, m_s) ? How many in total? For each what is the value of 'm', the z-component of $J=L+S$? What are the possible values of 'j'? What is the degeneracy of each value of 'j' (the number of 'm' substates)? Do they add up to the same number of as (m_l, m_s) ?
- Explain the Stern-Gerlach experiment which first observed electron spin. Why couldn't the experiment be explained in terms of normal orbital angular momentum?
- Describe how $L^2/2mr^2$ acts as an effective potential. Is it actually kinetic or potential energy? What is the corresponding 'force'?
- What force causes L to precess? Around what does it precess?
- Why is the degeneracy of an l-orbital equal to $g=2(2l+1)$?
- List two sets of quantum numbers that completely specify the state of an electron in the H atom. Note there is not a 1-1 correspondence of states in the two sets.
- What is the degeneracy of $n=1, 2, 3$ states in the H atom? What is it for arbitrary 'n'?
- What is the advantage of specifying substates in an orbital by (j, m) instead of (m_l, m_s) ?
- Explain the origin of the $L \cdot S$ spin-orbit interaction.
- Show that $L \cdot S = (j(j+1) - l(l+1) - s(s+1))/2 * \hbar^2$, so that the 'j' degeneracy is broken by the spin-orbit interaction, (ie. The energy is different for different 'j' states).