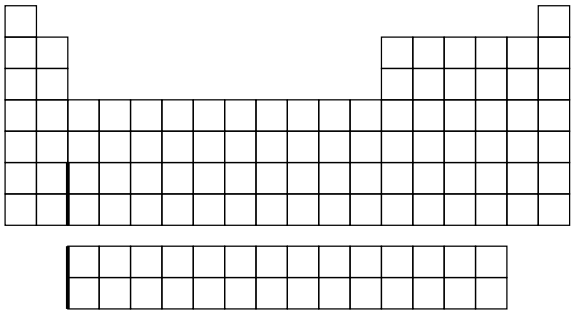
University of Kentucky, Physics 361
EXAM 3, 2009-04-17

Instructions: The exam is closed book and timed (50 minutes). [65 pts total]

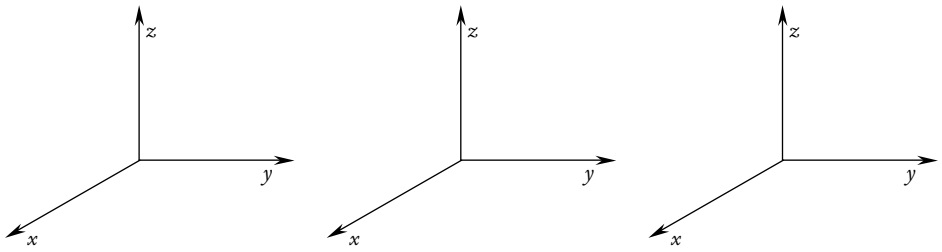
$$L^2 = l(l+1)\hbar^2 \qquad S^2 = l(s+1)\hbar^2 \qquad J^2 = j(j+1)\hbar^2$$
$$L_z = m_l\hbar \qquad S_z = m_s\hbar \qquad J_z = m\hbar$$
$$f_B = e^{-\alpha}e^{-E/kT} \qquad f_{BE} = \frac{1}{e^{\alpha}e^{E/kT}-1} \qquad f_{FD} = \frac{1}{e^{\alpha}e^{E/kT}+1}$$

[5 pts] 1. a) Complete the following table for all orbitals in the $n = 3$ shell of the hydrogen atom. g_ℓ is number of substates of ℓ, etc. The last column is the spectroscopic notation for that state. Shade in and label the groups of elements in the periodic table that have their outermost electrons in each of these orbitals.

ℓ	$g_l \cdot g_s$	j	g_j	term



[3 pts] 2. Sketch the regions of high probability on the following graph for hydrogen atom electron in the specified states:



1s $\qquad$ $3p_x$ $\qquad$ $3d_{yz}$

[2 pts] 3. Why does an atom with orbital angular momentum also have a magnetic moment?

[2 pts] 4. What two things are necessary for precession about a magnetic field?

[3 pts] 5. Match the following: (a) force (b) torque (c) potential with:
( ) $\boldsymbol{\mu} \times \boldsymbol{B}$, ( ) $-\boldsymbol{\mu} \cdot \boldsymbol{B}$, ( ) $\boldsymbol{\nabla}(\boldsymbol{\mu} \cdot \boldsymbol{B})$, and with:
( ) Stern-Gerlach, ( ) MRI, ( ) Zeeman effect.

[3 pts] 6. List 3 experimental evidence that electrons have an additional quantum number m_s.

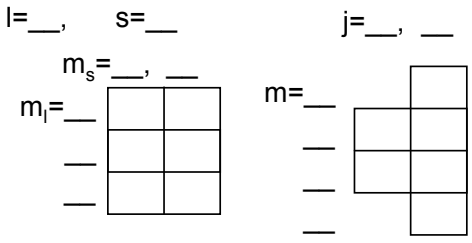
[2 pts] 7. Give two reason why spin angular momentum is not physical rotation of a particle.

[2 pts] 8. List two particles with different spin s, and the value of s of each.

[3 pts] 9. What is an observable effect of spin-orbit coupling and how does the coupling occur?

[2 pts] 10. Why do the inert gasses have atomic numbers Z=2, 10, 18, 36?

[5 pts] 11. Complete the following tables for the addition of angular momenta. Show which groups of states correspond with each other in the two tables.

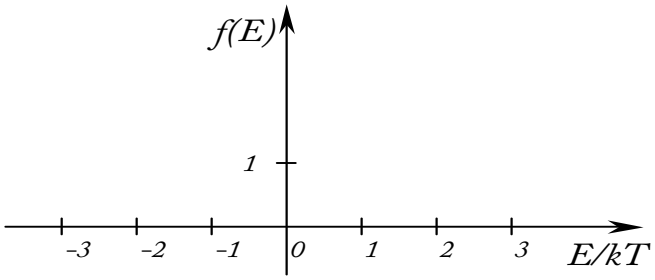


[2 pts] 12. Match the following particles (a) bosons, (b) fermions with:
( ) symmetric, ( ) antisymmetric wavefunctions.

[3 pts] 13. Give the definition of each part of $n(E) = g(E)\, f(E)$.

[4 pts] 14. List two applications of Bose-Einstein statistics and two of Fermi-Dirac statistics.

[5 pts] 15. Sketch a plot of the distributions $f_{MB}(E)$, $f_{BE}(E)$, and $f_{FD}(E)$, where $\alpha = 0$. Label which applies to fermions and which to bosons, and circle the features of the graph responsible for the Pauli exclusion principle and for the Bose-Enstein condensate (BEC).



[4 pts] 16. Give a statistical-mechanical explanation of the two-fluid model of liquid helium II.

[3 pts] 17. The Maxwell-Boltzman distribution of molecular velocities is

$$f(v) = N\left(\frac{m}{2\pi kT}\right)^{3/2} 4\pi v^2 e^{-mv^2/2kT}.$$

Circle the three parts of this equation and label where they came from. What should $\int_0^\infty f(v)dv$ equal? (don't integrate it!)

[2 pts] 18. Using statistical mechanics, write down the formula for the atmospheric pressure as a function of h, the height above sea level. Let P_0 be the pressure at sea-level.

[10 pts] 19. An MRI uses a 5 T magnetic field to thermally polarize the proton spins in your body, so that more are spinning down ($m_s = -\frac{1}{2}$) than up ($m_s = +\frac{1}{2}$). The magnetic energy of the states $m_s = \pm\frac{1}{2}$ is $U = \pm 2.79\mu_N \cdot B$, where $\mu_N = 31.5$ neV/T. Calculate the fraction of atoms in each state.