NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 283 – Modern Physics Fall 2026

Problem Set #9

Problem Set Due: Thurs., Nov. 19, 2026
Read Krane: Chapter 10

1. **OpenStax University Physics Vol. 3: Section 2.5:** Problem 67
2. **OpenStax University Physics Vol. 3: Section 2.7:** Problem 87
3. **OpenStax University Physics Vol. 3: Section 2.7:** Problem 89

4. Consider the case in which 6 non-interacting particles share 8 units of energy (where each particle is restricted to hold only integer units of energy). Draw the energy level diagram for the macrostates (see Fig. 10.3), and use the statistical methods outlined in Class or in Krane:

   (a) Treat the particles as identical but distinguishable. Calculate the *normalized* probabilities of finding a particle with 8,7,6,5,4,3,2,1, and 0 units of energy. That is, calculate $f(E=8), f(E=7), f(E=6), \ldots, f(E=0)$. Plot $f(E)$ verses E. This distribution is the Maxwell-Boltzmann distribution.

   (b) Treat the particles as identical but indistinguishable. Calculate the normalized probabilities of finding a particle with 8,7,6,5,4,3,2,1, and 0 units of energy. That is, calculate $f(E=8), f(E=7), f(E=6), \ldots, f(E=0)$. Plot $f(E)$ verses E. This distribution is the Bose-Einstein distribution.

   (c) Treat the particles as identical but indistinguishable and obeying the Pauli Exclusion Principle. Calculate the normalized probabilities of finding a particle with 8,7,6,5,4,3,2,1, and 0 units of energy. That is, calculate $f(E=8), f(E=7), f(E=6), \ldots, f(E=0)$. Plot $f(E)$ verses E. This distribution is the Fermi-Dirac distribution.

Redo Quiz problems are on the next page:

Each worth 25 points (problems 5-8)

5. Use Hund's Rule to find the ground state *L*, *S*, and *J* of the following below. For each element, *draw the energy level diagram (as was done in class) and showing all the spin up and down electrons* occupying the levels according to Hund's Rule. Explicitly show how you get the maximum *z*-components of the spin and orbital angular momenta.

(a) Bromine, configuration $\left[\mathrm{Ar}\right]3d^{10}4s^{2}4p^{5}$

(b) Iron, configuration $\left[\mathrm{Ar}\right]3d^{6}4s^{2}$

(c) Platinum, configuration $\left[\mathrm{Xe}\right]6s^{1}4f^{14}5d^{9}$

(d) Iron ion: Fe^{3+} (3 valence electrons removed—think carefully about which electrons are removed first)

(e) For each element above, write the ground state in spectroscopic notation.

6. The electronic configuration of nitrogen is: $1s^{2}2s^{2}2p^{3}$. Thus, nitrogen has 3 valence electrons in the outer *p* shell.

(a) What are the quantum numbers ℓ_1, ℓ_2, ℓ_3 and s_1, s_2, s_3 for the three valence electrons?

(b) Find all the allowed values of the total orbital and spin quantum numbers, L, S, and J for this system of 3 electrons.

(c) List all the possible quantum states for this $2p^3$ state by specifying each state with the

(1) quantum numbers $\left(L, S, J\right)$ and

(2) in spectroscopic notation

(*as was done in class for the carbon example*).

(d) Use Hund's rules to find which $\left(L, S, J\right)$ state is the lowest energy state (the ground state) of this system.

7. Transitions occur in an atom between a 3*d* and 2*p* state in a magnetic field of $B = 0.5\,\mathrm{T}$.

(a) *Draw the energy level diagram* for these states when the external magnetic field is off and on (*as was done in Krane*).

(b) On the same diagram, *draw all the possible transitions* from the 3*d* to the 2*p* states that satisfy the magnetic dipole selection rules.

(c) On the same diagram (next to each energy level), write the energy of each energy level *(as was done in class)*.

The energy of the 3*d* and 2*p* states for zero field are E_{3d} and E_{2p}. The wavelength observed before the field was turned on was $\lambda = 5000\,\text{Å}$.

(d) Determine the final wavelengths observed in terms of B, E_{2p}, E_{3d}, μ_B, h and c for each of the 9 transitions (*show explicitly how you get the wavelengths as if you are explaining this to a high school student—you must derive the formula [just writing down a formula gets no credit]*).

(e) Numerically calculate the final wavelengths observed.

8. Quiz #3, Problem #4 (worth 25 points)

posted on the Physics 283 Website: www.niu.edu/brown

You will find a link to a Word document. Use Microsoft Word (or any program that can read Microsoft Word (like Google Sheets or OpenDoc).

(a) Use Microsoft Word to draw the ray diagram (using menu functions: *insert* → *shapes* → *line*).

(b) Do the numerical lens calculations to show that the ray tracing results are correct.