PHYSICS 215 - Midterm Exam 3 Name: ______________________________

Please open the exam when I give the word.
There are more than 100 points available. Attempt as many points as you wish.
Your score will be your points divided by 100.

Be sure to write out your algebra!

If you're stuck, still write out what you *can* show.
Then go on to other parts.

If you are missing a previous answer for a further step, define a symbol for that answer, and calculate the next step *symbolically* in terms of the previous result.

Use the back sides of sheets for scratch paper

Useful Constants:

a_o = 5.2918 E-11 m
$\alpha = e^2/4\pi\varepsilon_0 \hbar c$ = .0072874 ~ 1/137
c = 2.9979 E8 m/s
e = 1.6022 E-19 C
$1/4\pi\varepsilon_0$ = 8.9876 E9 Nm^2/C^2
$e^2/4\pi\varepsilon_0$ = 1.4400 E-9 eV•m
$E_o(H)$ = -13.606 eV
h = 6.6261 E-34 J.s = 4.1357 E-15 eV•s
$\hbar = h/2\pi$ = 1.0546 E-34 J.s = 6.5821 E-16 eV•s
hc = 1239.8 eV•nm
$\lambda_c = h/m_e c$ = 2.4263 E-12 m
m_α = 3727.4 MeV/c^2 = 4.00151 u
m_e = 9.1094 E-31 kg = 511.00 keV/c^2 = 5.49E-4 u
m_p = 1.6726 E-27 kg = 938.27 MeV/c^2 = 1.00728 u
μ_B = 5.79E-5 eV/T
N_A = 6.0221 E23 mol^{-1}
R_∞ = 1.09737 E7 m^{-1}
u = 1.66E-27 kg = 931.5 MeV/c^2

Problem #1 _____ [15 max]

Problem #2 _____ [25 max]

Problem #3 _____ [25 max]

Problem #4 _____ [30 max]

Problem #5 _____ [30 max]

Total _____[125 max]

1. [15] Consider an atom of Nitrogen, $Z = 7$.
    a. [5] Write out the electron configuration in terms shells and subshells. Explain why you chose this configuration.

    b. [10] Write out the hydrogen state quantum numbers for each electron, and describe the basis on which you are choosing these particular quantum numbers. If some are arbitrary choices, indicate which ones.

2. [25] The ground state of Si_{14} has an outer electron configuration of $3s^2 3p^2$.
    a. [10] What values of the quantum numbers S, L, J are possible for the electrons which are not in closed subshells?

    b. [15] Using your results from a), give the spectroscopic notation for what you expect to be the ground state configuration, and explain why you expect this to be the ground state.

3. [25] An atom with a state $^3D_2$ is placed in a **weak magnetic field**.
   a. [10] Sketch the energy levels for each state, explaining why you draw the levels as you do. *Hint*: indicate the relevant quantum numbers of each state.

   b. [10] Find the g factor for this state.

   c. [5] Find the value of the energy splitting (in eV) among the $^3D_2$ substates for a magnetic field of 0.1 Tesla. (if you can't find g, do the calculation with g = 1)

4. [30] Consider an electron trapped in a 2-dimensional square infinite potential well, whose energy levels are given by $E_{mn} = (m^2 + n^2)\ 1.0$ eV.

   a) [16] Fill in the table below for the ***four lowest distinct energy levels***, and whether the state is degenerate; if so, give the alternative quantum numbers with the same energy.

Level:	m	n	E (in electron Volts)	degenerate?
Ground	_____	_____	________	________
1st excited	_____	_____	________	________
2nd excited	_____	_____	________	________
3rd excited	_____	_____	________	________

   b) [9] Draw a diagram showing with arrows the transitions among these states starting with an electron in the 3rd excited state.

   c) [5] List the *distinct* photon energies emitted in such transitions.

5. [30] Consider an electron bound by a 1-D infinite potential well surrounding x=0 to x=L.
    a. [4] Sketch the wave function for the ground state.

    b. [3] Write the expression for the probability for the electron to be found between x=0 and x= L/4. Then calculate or estimate this probability.

    c. [4] Sketch the wave function for a much higher energy, say 1000 x Eground.

    d. [3] Use your sketch to estimate the probability for the electron to be found between x=0 and x = L/4 (no integral required).

    e. [3] Explain qualitatively the difference, if any, between these probabilities.

The next questions are independent of 5a-e:

    f. [4] What is the expected value of x, and of p? Why?

    g. [4] What is the side L of the potential well with a ground state energy of 1.0 eV?

    h. [5] For what uncertainty Δx (in terms of L) would the minimum estimated kinetic energy equal the actual ground state energy?