Midterm Examination for

Introduction to Nano Science and Technology A(1)

Name: _____   I.D.#: _____

(Please use a separate sheet(s) for your answers)

[Useful Constants: speed of light $c = 3 \times 10^8$ m/s; Planck's constant $h = 4.14 \times 10^{-15}$ eV-s; electron rest mass $m_e = 9.1 \times 10^{-31}$ kg; Coulomb's law constant $1/4\pi\varepsilon_0 = 8.99 \times 10^9$ nt-m^2/coul^2]

1. Please concisely describe the following terms: (20 pts)
   a. Wave-particle duality:
   b. Uncertainty principle:
   c. Physical meaning of wave functions:
   d. Electron spin:
   e. Covalent bond:

2. (a) Evaluate, in electron volts, the energies of the three levels of the Helium ion He$^+$ in the states for n = 1, 2, 3. [Hint: $E_n = -13.6\ (Z^2/n^2)$ eV] (6 pts)
   (b) Then calculate the frequency in hertz, and the wavelength in angstroms, of all the photons that can be emitted by the atom in transitions between these levels. (6 pts)
   (c) For the hydrogen atom, the location at which the radial probability density is a maximum for the $n=2$, $l=1$ state is indicated in the attached figure by a dashed line, and the expectation value of the radial coordinate for this state is marked with a small triangle. Write down these two values and explain the physical significance of the difference between these two. (8 pts)

3. Consider a particle approaching a step potential V(x). Here V(x) = 0 for $x \le 0$; $V(x) = V_o$ for $x > 0$. (20 pts)
   (a) Write down the solution for the eigenfunctions and eignvalues for $E < V_0$.
   (b) Also find the solution for the eigenfunctions and eignvalues for $E > V_0$.

4. (a) For a particle in a one-dimensional infinite square well (well width a), write down the first three eigenfunctions and eigenvalues. (10 pts)
   (b) Then show that the fractional difference in the energy between adjacent eigenvalues is

$$\frac{\Delta E_n}{E_n} = \frac{2n+1}{n^2}$$ (5 pts)

(c) Use this formula to discuss the classical limit of the system. (5 pts)

5. (a) Determine the ground state configurations for the atoms ^{19}K and ^{17}Cl. (5 pts)
    (b) Then describe the bonding nature and its physical origin of a KCl molecule. (5 pts)
    (c) From the following data, find the energy required to dissociate a KCl molecule into a K atom and a Cl atom. The first ionization potential of K is 4.34 eV; the electron affinity of Cl is 3.82 eV; the equilibrium separation of KCl is 2.79 Å. [Hint: The mutual potential energy of K^+ and Cl^- is $-(14.40/R)$ eV if R is given in Angstroms] (10 pts)
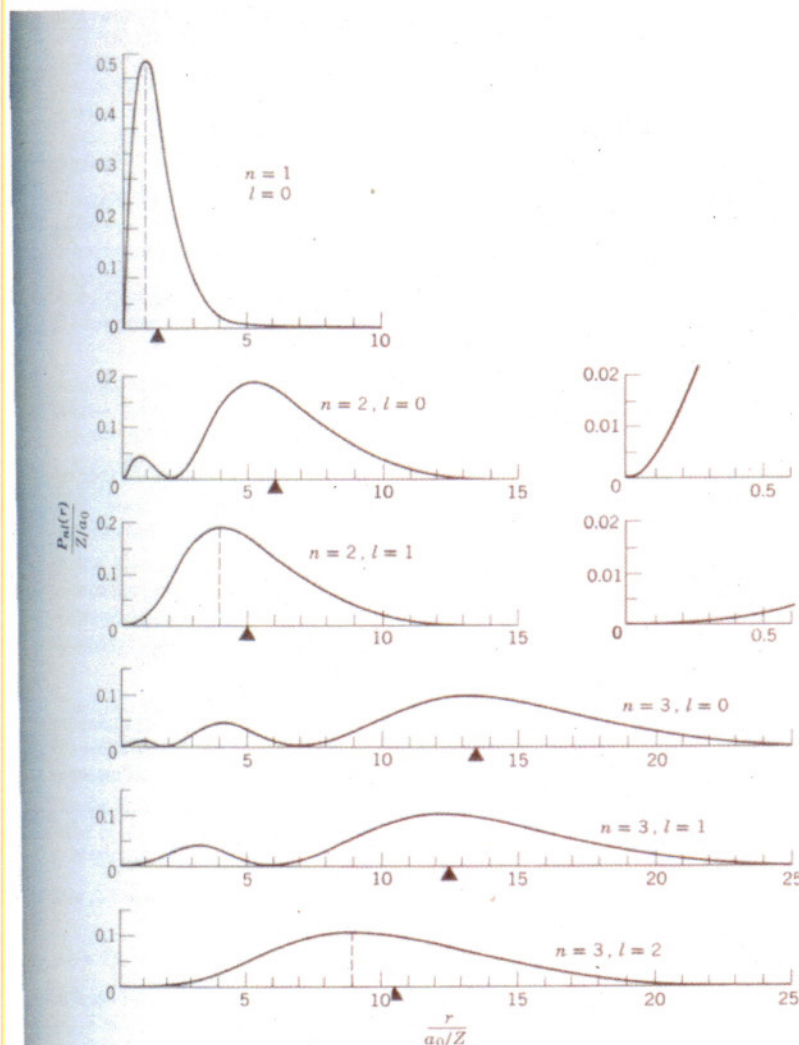
Attached Figure

Figure 7-5 The radial probability density for the electron in a one-electron atom for $n = 1, 2, 3$ and the values of l shown. The triangle on each abscissa indicates the value of $\bar{r}_{nl}$ as given by (7-29). For $n = 2$ the plots are redrawn with abscissa and ordinate scales expanded by a factor of 10 to show the behavior of $P_{nl}(r)$ near the origin. Note that in the three cases for which $l = l_{max} = n - 1$ the maximum of $P_{nl}(r)$ occurs at $r_{Bohr} = n^2 a_0/Z$, which is indicated by the location of the dashed line.