Exam 2 --- 2004 --- SOLUTIONS

I. Multiple choice

1.b., 2.d., 3.c., 4.a., 5.c.

II. a. $k_1^2 = 2mE/\mathbf{h'}^2$, $k_1=3.8\times10^{11}m^{-1}$ (**h'** is meant to be h-bar)
$\lambda=1.7\times10^{-11}m$.
b. Propagates, since E > V = 2.5 eV. So $\mathbf{h'}^2k_2^2/2m + 2.5$ eV = 3.0 eV or $\mathbf{h'}^2k_2^2/2m = 0.5$ eV.
Then $k_2 = 1.55\times10^{11}m^{-1}$.

III. a. Take the 2nd derivative of the wavefunction ψ with respect to x and obtain $-k^2\psi$. Then the left hand side of the equation is $-(\mathbf{h'}^2/2m)(-k^2)\psi$ and the right hand side is just $E\psi$;
the ψ cancels out showing that this is a solution, providing the constant factors are equal.
b. $(\mathbf{h'}^2/2m)k^2 = E$
c. At x=0 and L the wavefunction must vanish. So $kL=n\pi$. Hence $k=n\pi/L$.
d. $E_n=(h^2/8mL^2)(n^2)$
e. 2 electrons can occupy the lowest energy state, n=1. The 3rd and 4th electron must go to the next highest level, n=2, the 5th and 6th to n=3, and so on, until all N electrons are accounted for. So the last pair will be in the n=N/2 level.
The last electron will thus have energy $E=(N/2)^2(h^2/8mL^2)=(h^2/32m)(N/L)^2$.
f. Bosons can all occupy the same energy state, so n=1 and $E= (h^2/8mL^2)$.

IV. a. $1s^22s^22p^63s^23p^64s^1$
Note highest is in 4s not 3d.
b. $-Z^2E_0/n^2 = -19^2\times13.6/4^2$ eV = 307 eV
c. $-Z_{screen}^2E_0/16=4.34$ eV, so $Z_{screen}=2.26$
d. Must add 4.34 eV to ionize K. 3.6 eV is released when Cl absorbs electron.
So net of 0.74 eV must be added to pair of atoms.

V. a. 1s state is allowed (with opposite m_s to other electron).
$E_{1s}= -Z_{screen}^2E_0/1 = -24.8$ eV.
b. 3d -> 2p -> 1s, each step must have $|\Delta l|=1$.
c. $E(3d)-E(2p)=-Z_{screen}^2E_0/9 + Z_{screen}^2E_0/4 = 3.4$ eV
$E(2p)-E(1s)= -Z_{screen}^2E_0/4 + Z_{screen}^2E_0/1 = 18.6$ eV
Then $\lambda_{3,2}=hc/(3.4\text{ eV}) = 3.6\times10^{-7}$ m
and $\lambda_{2,1}=hc/(18.6\text{ eV}) = 6.7\times10^{-8}$ m.