EMSE314--Fall 2003--Homework 3--Name: ____________________

Issued: Oct. 01, Due: Oct. 13.

(4 Problems, 50pts +5 bonus pts)

Problem 1—"photoelectric effect" *(20 pts)*

The incident light wavelength vs. photoelectric voltage on sodium metal is given as the following: (after R.A. Millikan, Phys. *Rev.*, **7** (1916), 355)

λ, nm	312.5	365.0	404.7	433.9	546.1
$-\varepsilon$, volt	2.128	1.595	1.215	1.025	0.467

(a) Calculate the work function of sodium in eV and the Planck constant. *(6 pts)*

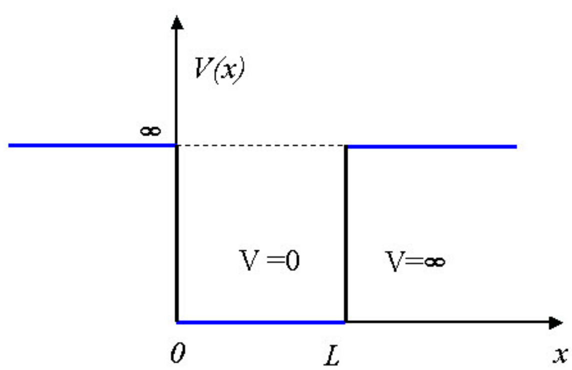
(b) If the sodium surface is bombarded by a Mg K_α X-ray ($h\nu = 1250$ eV), calculate largest possible kinetic energy of the photoemitted electrons in eV. Given the ***binding energy*** of Na 1s, 2s, and 2p states are 1070eV, 64eV, and 31 eV, respectively; calculate the kinetic energy of electron emitted from these states. Why are they different? *(8 pts)*

(c) Suppose the sodium surface is incident by UV lamp with wavelength between 150-370nm and a maximum density of 20 mW/cm^2 at 254nm, what will be the maximum photoelectric current density? *(3 pts)*

(d) Suppose the sodium surface is incident by a tungsten lamp (Refer to *Figure 3.11* in the textbook) working at 2500K with an intensity of 20 mW/cm^2, what will be the maximum photoelectric current density? *(3 pts)*

Note: Suppose the light generated by UV lamp and W lamp are both monochromic, which adopts the maximum intensity (In real world, this is not a good assumption).

Problem 2--"particle in a box" *(15 pts+5pts)*



(a) For a particle in a potential well as shown in the diagram, derive the wave function and energy by solving the Schrödinger equation. *(7 pts)*

(b) For an electron at the center of potential well, determine if transitions $1 \rightarrow 2$ and $1 \rightarrow 3$ are possible. *(8 pts)*

Hint: The probability of transition $p \rightarrow q$ *is proportional to* $R_{p\rightarrow q} = \left| \int_0^L [\psi_p \bullet (x - \frac{L}{2}) \bullet \psi_q] dx \right|$

where $\Psi_p(x)$ *and* $\Psi_q(x)$ *are wave functions for integer n=p and n=q, respectively.*

(c) Guess the selection rule for the particle in a box. *(+5 points)*

Problem 3—"Heisenberg uncertainty principle" *(5 pts)*

An excited electron in a sodium atom emits a radiation of wavelength 589 nm and returns to the ground state. If the mean time for the transition is about 20 ns, calculate $\Delta\lambda$, the inherent width of the emission in the sense of wavelength.

Problem 4--"hydrogenic atom" *(10 pts)*

The solution to Schrödinger equation of hydrogenic-atom when n=2 is given as

$$\psi_1 = \frac{1}{4\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} \rho\, e^{-\frac{\rho}{2}} \cos\theta$$

$$\psi_2 = \frac{1}{4\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} \rho\, e^{-\frac{\rho}{2}} \sin\theta\cos\phi$$

$$\psi_3 = \frac{1}{4\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} (2-\rho)\, e^{-\frac{\rho}{2}}$$

$$\psi_4 = \frac{1}{4\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} \rho\, e^{-\frac{\rho}{2}} \sin\theta\sin\phi,$$

where $\rho = \frac{Zr}{a_0}$, Z is atomic number.

(a) Identify *l* and *m* for each function. Show your reason. *(6 pts)*

(b) Which wave function denotes 2s state? How about $2p_x$, $2p_y$, and $2p_z$ state? *(4 pts)*

Hint: consider the symmetry of each function.