

State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions

For all problems, use $c = 2.998 \times 10^8$ m/s.

“I’ve been workin’ on the work function, all the live long day...” (50,000 points)

1.) The work function of copper (Cu) is given in Table 2.1 (Serway M&M) as 4.70 eV. (a) Find the frequency of light that would release an electron from a sodium surface with essentially no kinetic energy.

(b) Find the frequency of light that would release an electron from a sodium surface with a speed of 10.0% that of light.

(c) We haven’t yet completely talked about how atoms are put together, but the Cu atom has 29 electrons. That means the outside electron would be effectively in the $n = 4$ orbital somewhere. Consider a hydrogenic copper ion, Cu^{28+} , where we can use the Bohr atom. Find the energy needed to remove an $n = 4$ electron from Cu^{28+} .

(d) Find the frequency of the photon needed in part (c). Does this frequency compare more to the answer in (a) or the answer in (b) or neither?

(e) Find the deBroglie wavelength of the $n = 4$ electron in Cu and compare it to the *Compton wavelength of the electron*, which is $\frac{h}{m_e c} = 0.0243 \text{ \AA}$. Note: In Compton Scattering, is the electron more of a wave or a particle?

“Quantum Boxes, Quantum Boxes, All Made Out of Ticky-Tacky...” (50,000 points)

2.) Consider a quantum particle (an electron, $m_e = 9.11 \times 10^{-31}$ kg) in a box $a \leq x \leq b$, where $a = -0.500 \text{ \AA}$ and $b = +0.500 \text{ \AA}$. Inside the box, the potential energy is $U(x) = 0$ and outside $U(x) = +\infty$. The general solution for such a problem is:

$$\Psi_n = A_n \cos(k_n x) + B_n \sin(k_n x)$$

(a) For the ground state, $n = 1$, find the solution for all the constants in the problem. *Don’t bother to normalize the function.*

(b) For the ground state, $n = 1$, find the energy E_n .

(c) If the electron has $E = E_1$ and $U(x) = 0$, then find the speed v from the classical kinetic energy, $K = \frac{1}{2}mv^2$.

(d) The particle must be contained in its box of width 1.00 \AA . Use the Heisenberg Uncertainty Principle to find the uncertainty in momentum, Δp_x . Does this value change depend on which state n we are in?

(e) Use the Heisenberg Uncertainty Principle to find the uncertainty in time, choosing ΔE to be 1.00% of E_1 . Compare this to the time it takes the classical electron to cross the width of the 1.00 \AA width of the box.