Assignment VI, PHYS 230 (Introduction to Modern Physics)
Spring 2017
Due Wednesday, 3/1/17 at start of class

1. In class, we talked about how the mass of a full nucleus is smaller than the sum of the masses of the constituent parts when they are pulled apart. Our physical interpretation of this comes from the fact that some of the mass-energy of the neutrons/protons is converted in to energy to hold the nucleus together.

   a) Based merely on the masses and numbers of protons and neutrons in the nucleus, what would you expect the mass of a ^{192}Os nucleus to be (in GeV/c^2)?

   b) The actual mass of this nucleus is observed to be 191.9615u. What is the binding energy of this nucleus? (Put another way – if you physically took the nucleus apart into individual neutrons and protons, how much energy would you release?)

2. A fission reaction that can actual occur is ^{239}Pu + ^{1}n $\rightarrow$^{91}Sr + ^{146}Ba+3^{1}n. Where "n" indicates a neutron. Given that the mass of ^{239}Pu is about 239.0521634u, the mass of ^{91}Sr is about 90.9102031u, and the mass of ^{146}Ba is about 145.93022u – how much energy is released in this decay?

3. I have a ping-pong ball in my office with a diameter of 40mm (regulation size, because I take my ping-pong seriously). If this ping-pong ball was a blackbody and held at a constant temperature of 15°C:

   a) How much energy would it emit in a year? (Leave your answer in Joules).

   b) What is the peak wavelength of blackbody emission?

4. The work function of Molybdenum is 4.22 eV.

   a) What is the threshold frequency for the photoelectric effect in Molybdenum?

   b) Will yellow light of wavelength 560 nm cause ejection of photoelectrons from Molybdenum? Prove your answer.

5. A photoelectric experiment with Cesium yields stopping potentials for $\lambda = 435.8$ nm and $\lambda = 546.1$ nm to be 0.95 V and 0.38 V, respectively. Using these data only, find the threshold frequency and work function for Cesium and the value of h.

6. One of the funky things that didn't follow the classical expectation for the photoelectric effect is that there was no time-lag between turning on the light-source and measuring a current. In practice – if we don't know about or believe the quantum hypothesis – then we would expect there to be some finite amount of time between when you turn on the source and when a typical electron could gain enough energy from the light beam to be liberated. Let's try and ballpark this expected time-lag for a weak source.

   a) Assume a lightbulb emits total power P equally in all directions. Let us put a metal surface X meters away from this light source, and let's assume it takes energy ϕ to liberate an electron from an atom in this metal. Assuming an atom has a circular cross-section of D, how long would it take for the atom to gain energy ϕ from the source? Leave your answer in terms of P, X, ϕ, and D. (Hint: To check your answer, make sure that it makes sense. The larger P is, the less time it should take. The larger X is, the longer it should take. The higher ϕ is, the longer it should take, and the larger D is, the shorter it should take. That should tell you something about the form of the answer.)

   b) Find the actual value of the time-lag as designed in part a if P is 2 W, X is 0.1 m, ϕ is 6 eV, and D is 0.1 nm.

   c) Assuming that the photon hypothesis is correct (and that photons travel at c), how long would you expect the time-lag to be? Again, assume that $\phi = 6$ eV, that the wavelength of the light is 100 nm, and assume that the path the electron takes through the tube is a straight-line path (no acceleration once liberated). You may ignore relativistic effects for the electron.