PHYS 201 WINTER 2010

HOMEWORK 5

Write down all steps towards the solution to obtain maximum credit. Don't forget to specify units!

1. Blue Laser

A laser produces a beam of photons, each with wavelength 420 nanometers. It is aimed at a calcium plate and electrons escape the plate via the photoelectric effect. **How much kinetic energy, in Joules, does the most energetic electron have after it escapes?** Use 2.87 eV as the work function of calcium.

2. Photons and Electrons

Photons of energy 5 eV are incident on an electron emitter with the total absorbed power of 2 mW and a work function 3 eV.

2.1. **Calculate the wavelength of incoming photons.**

2.2. **How many photons per second hit the emitter?**

2.3. **What is the maximum kinetic energy of the emitted photoelectrons?**

2.4. **For what range of voltages between the emitter and collector will the photocurrent be significantly greater than zero?**

2.5. **Calculate the fraction of photons that are absorbed by the emitter and which contribute to the photocurrent.** Assume the measured photocurrent at positive voltage is 200 pA $= 200 \cdot 10^{-12}$ A.

3. Color Me Excited

When the electron in a hydrogen atom is in an excited state, it can jump to a less-excited state by emitting a photon. Photons are emitted only at certain wavelengths such as the ones shown in the picture.

The visible wavelengths, called the *Balmer series*, are given by the *Rydberg formula*, which can be found in your textbook or online. **Calculate the four longest wavelengths, in nanometers, of the Balmer series.**

4. A Speedy Electron

Bohr's model of the hydrogen atom consists of a tiny, negatively charged electron in orbit around a tiny, positively charged proton - much like a planet orbiting a sun, but with electrical instead of gravitational attraction.

Bohr assumed that only circular orbits with radius $r_n = n^2 a_0$ were allowed, where $n = 1, 2, 3, \ldots$ and a_0 is an empirical constant. In this model, an electron orbiting a proton has total energy (kinetic + potential) equal to:

$$E_n = K + U = \frac{1}{2}mv^2 - \frac{ke^2}{n^2 a_0}$$

where the constants in this expression are:

a_0	Bohr radius $\approx 5.29 \cdot 10^{-11}\ m$
m	mass of electron $\approx 9.11 \cdot 10^{-31}\ kg$
k	Coulomb force constant $\approx 8.99 \cdot 10^{9}\ Nm^2/C^2$
e	elementary charge $\approx 1.60 \cdot 10^{-19}\ C$

The energy of the nth orbit is known to be (approximately)

$$E_n = -13.6\ eV \left(\frac{1}{n^2}\right)$$

Calculate the velocity, in m/s, of an electron in the $n = 2$ orbit.
Hint: If your answer is faster than the speed of light, try again.

5. Bonus Problem

Consider the electron in the $n = 2$ orbit around a proton from problem #5. It has some angular momentum $L_2 = m_e vr$ where v is the velocity you just calculated and $r = 4a_0$ is the radius of the second Bohr orbit.

The electron can "jump" to the $n = 1$ state by emitting a photon. In the $n = 1$ state, the electron has a new (smaller) angular momentum L_1. Angular momentum can't just disappear, so the photon must have angular momentum $L_p = L_2 - L_1$. **Use the Bohr model to calculate the angular momentum of a photon emitted by the $n = 2$ to $n = 1$ transition in a hydrogen atom.**