PC2232 Physics for Electrical Engineers: Tutorial 4

Question 1: Photoelectric effect

A 2.50 W beam of light of wavelength 124 nm falls on a metal surface. You observe that the maximum kinetic energy of the ejected electrons is 4.16 eV. You may assume that each photon in the beam ejects a photoelectron.

(a) What is the work function (in eV) of this metal?

(b) How many photoelectrons are ejected each second from the metal?

(c) If the power of the light beam, but not its wavelength were reduced by half, what would be the answer to part (b)?

(d) If the wavelength of the beam, but not its power, were reduced by half, what would be the answer to part (b)?

(e) Explain whether the maximum kinetic energy of the photoelectrons is changed in parts (c) and (d).

Question 2: Compton Effect

(a) Derive an expression for the total shift in photon wavelength after two successive Compton scatterings from electrons at rest. The photon is scattered by an angle θ_1 in the first scattering and θ_2 in the second.

(b) In general, is the total shift in wavelength produced by two successive scatterings of angle $\theta/2$ the same as by a single scattering of θ? If not, are there any specific values of θ, other than $\theta = 0$ for which the total shifts are the same?

(c) Use the result of part (a) to calculate the total wavelength shift produced by two successive Compton scatterings of 30.0° each. Express your answer in terms of h/mc.

(d) What is the wavelength shift produced by a single Compton scattering of 60.0°? Compare to the answer in part (c).

Question 3: Atomic Spectra

What is the radius of the first Bohr orbit and ionization energy in each of the following:

(a) He^{+} ion,

(b) Li^{2+} ion, and

(c) Be^{3+} ion?

Question 4: Atomic Spectra

A non-relativistic particle with mass m is held in circular orbit around the origin by an attractive force $F(r) = -Dr$, where D is a positive constant. Use the Bohr model idea that only certain values of the angular momentum are allowed to answer the following questions.

(a) What are the allowed values of the orbital radius?

(b) What are the allowed energies? (Let the potential energy be zero at $r = 0$)

(c) If the particle is excited, it will decay back down to the ground state by emitting one or more photons. What are the possible photon energies?

(d) Describe a possible physical situation in which this problem corresponds.

Question 5: Atomic Spectra (Optional)

(a) Show that in the Bohr model, the frequency of revolution of an electron in its circular orbit around a stationary hydrogen nucleus is $f = me^4/4\epsilon_0^2 n^3 h^3$.

(b) In classical physics, the frequency of revolution of the electron is equal to the frequency of the radiation it emits. Show that when n is very large, the frequency of revolution does indeed equal the radiation frequency calculated for a transition from $n_1 = n + 1$ to $n_2 = n$.

(This illustrates Bohr's *correspondence principle*, which is often used as a check on quantum calculations. When n is small, quantum physics gives results that are very different from those of classical physics. When n is large, the differences are not significant, and the two methods then "correspond". In fact, when Bohr first tackled the hydrogen atom problem, he sought to determine f as a function of n such that it would correspond to classical results for large n.)