HW 4. Due Thu Oct 11 at 10 a.m. in my mailbox

Problem 1.

Electron in the first Bohr orbit (with $n = 1$) of hydrogen atom absorbs photon with energy 1.936×10^{-18}J. On which stationary orbit it will end up?

First, $1.936 \times 10^{-18}\text{J} = 12.1$ eV. Next, the energy of the n-th level is

$$E_n = \frac{E_0}{n^2}$$

with E_0 = -13.6 eV so

$$E_{\text{final}} = -13.6\text{eV} + 12.1\text{eV} = 1.5\text{eV} \simeq \frac{13.6\text{eV}}{9}$$
$$\Rightarrow \quad n_{\text{final}} = 3$$

Problem 2

Problem 4.41:

(a) The current i due to a charge q moving in a circle with frequency f_{rev} is qf_{rev}. Find the current due to the electron in the first Bohr orbit of hydrogen atom.

$$i = qf = e\frac{mk^2e^4}{2\pi\hbar^3} = 1.054 \times 10^{-3}\text{A}$$

(b) The magnetic moment of a current loop is iA, where A is the area of the loop. Find the magnetic moment of the electron in the first Bohr orbit in units A·m^2. This magnetic moment is called a *Bohr magneton*.

$$\mu = i\pi a_0^2 = \frac{e\hbar}{2m} = 9.27 \times 10^{-24}\text{A} \cdot \text{m}^2$$

Problem 3.

Problem 4.44:

Consider the Franck-Hertz experiment with Hg vapor in the tube and the voltage between the cathode and the grid equal to 4.0 V, i.e., not enough for the electrons to excite the Hg atom's first excited state. Therefore, the electron-Hg atom collisions are elastic.

(a) If the kinetic energy of the electrons is E_k , show that the maximum kinetic energy that a recoiling Hg atom can have is approximately $4mE_k/M$, where M is the Hg atom mass.

Maximal recoil energy occurs in a head-on collision so

$$E_{\rm Hg} \;=\; E_k - E_k' \;=\; \frac{mv^2}{2} - \frac{mv'^2}{2} \;=\; \frac{M}{2}v_{\rm Hg}^2$$

Conservation of momentum:

$$mv \;=\; Mv_{\rm Hg} - mv' \quad\Rightarrow\quad v_{\rm Hg} \;=\; \frac{m}{M}(v+v')$$

From conservation of energy we get

$$v^2 - v'^2 \;=\; (v-v')(v+v') \;=\; \frac{M}{m}v_{\rm Hg}^2 \;=\; \frac{m}{M}(v+v')^2 \quad\Rightarrow\quad v-v' \;=\; \frac{m}{M}(v+v') \quad\Rightarrow v \simeq v'$$

so $v_{\rm Hg} \;\simeq\; \frac{2m}{M}v$ and

$$E_{\rm Hg} \;=\; \frac{2m}{M}v^2 \;=\; \frac{4m}{M}E_k$$

(b) What is the approximate maximum energy that can be lost by an electron with $E_k =$ 2.5eV?

$$E_k - E_k' \;=\; E_{\rm Hg} \;=\; \frac{4m}{M}E_k \;\simeq\; \frac{4m}{200m_p}E_k \;=\; 2.7\times10^{-5}\text{eV} \;=\; 4.3\times10^{-23}\text{J}$$