PHY 491 - 2013

Atomic, Molecular, and Condensed Matter Physics

Problem Set 1

1. Find the ground state energy of a positronium atom, a system that reminds a hydrogen atom except that the proton is replaced with a positron. Express the energy in electron-volts and in joules. (4 pt)

2. In semiconductors, there are hydrogen-atom like objects called donors. You can think of a donor as a point-like positive charge $+e$ with an infinite mass, which can bind an electron as a proton binds an electron in the hydrogen atom. The difference from a hydrogen atom is that the whole system is in a dielectric, therefore the energy of the Coulomb coupling between the charges is reduced by a factor $1/\epsilon$, where ϵ is the dielectric constant, which can be quite large (~ 11.7 in silicon). Also, an electron is often "lighter" than in free space. As we will learn, it can be described by an effective mass m_{eff}. Find the ground state energy of an electron coupled to a donor. Estimate this energy for $\epsilon = 12$ and $m_{\text{eff}} = 0.2m_e$ (10 pt)

3. Of much current interest are Rydberg atoms. These are generally more complicated atoms than hydrogen, but in a Rydberg atom one electron is excited into a state with a large principal quantum number n, and then its energy spectrum can be described in the same way as for a hydrogen atom. Use the Bohr theory to find the characteristic "size" of a Rydberg atom with $n = 1000$. Calculate the binding energy of the electron in this state (5+1 pt)

The solution is due on September 11.