Quantum Mechanics I - Module 8

Consider the hydrogen atom and its eigenstates, omitting effects due to fine structure.

1. For the hydrogen eigenstate |210) determine the

    (a) expectation value of the energy
    (b) expectation value of the total orbital angular momentum
    (c) expectation value of the z component of orbital angular momentum
    (d) expectation value of the x component of orbital angular momentum
    (e) possible values of total angular momentum

2. Now replace the electron with a muon, which has a mass of $m_\mu \approx 200\ m_e$.

    (a) What is the ratio of the ground state energy of the muonic atom to that of the hydrogen atom?
    (b) What is the ratio of the wavelength of a transition from the n = 2 to the n = 1 state of the muonic atom to that of hydrogen?

3. Consider the hydrogen atom (ignoring the spin-orbit interaction), with eigenfunctions given by the chart on page 243 of your textbook.

    (a) For a given eigenfunction ψ_{nlm}, what is the energy?
    (b) Consider the *r* dependence:
        (1) Find the expectation value of *r* for the $n = 1$, $l = 0$ state by explicit calculation. Check units.
        (2) Do you expect the expectation value of *r* for, say, the $n = 2$, $l = 0$ state to be bigger or smaller? Why?

4. Suppose we had singly ionized helium (2 protons and 2 neutrons in the nucleus, one electron) instead of hydrogen.

    (a) By what factor would the energy levels E_n change with respect to hydrogen?
    (b) By what factor would the fractional energy spacing $E_{n+1} - E_n$ change with respect to hydrogen?