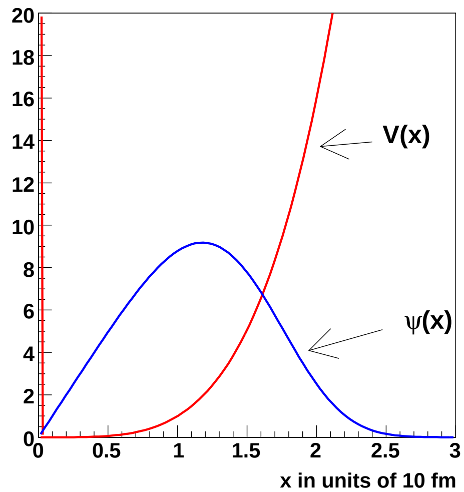
A schematic plot of the ground state wave function of a proton inside a nucleus is shown below. The units on the y axis are abitrary since the wave functions are not normalized. The units on the x axis are: $1 unit = 10\text{Fm}$ where $1\text{Fm} = 10^{-15} m$. (1 Fm known as a femto-meter or a fermi.)



a. Make an order or magnitude estimate for the Kinetic, Potential , and total energies based on this figure.

b. Treat the nucleus as 1D box of size L, determine the L which would give the same energy as you estimated in part a.

c. Suppose the proton were in this 1D box and decayed from the first excited state down to the ground state, what would the energy be of the emitted photon.

Consider modelling the vibrations of HCl, made up of hydrogen and clorine atoms in an ionic bond. Make a schematic model of these vibration by considering the clorine to be very heavy (it is 35 times heavier than the hydrogen atom). Then the force between the hydrogen and the clorine is approximately proportional to the displacement x of the hydrogen from its equilibrium position. This means that the potential is like a spring, $\frac{1}{2}kx^2$. The energy of between the ground state and first vibrational state is $0.35\,eV$.

- Determine the effective spring constant k express your answer in $eV/(nm^2)$ (Hint, what is the energy between the ground state and first excited states of the harmonic oscillator.)

- Write down the lowest order wave function of the hydrogen atom and make a qualitative sketch of the wave functions for the ground. (You do not have to substitue numbers in this part)

- Determine the variance in position (i.e. Δx of the hydrogen atom). Determine your answer first analytically and then substitute numbers.

- Determine the average potential energy felt by the hydrogen atom in eV. (Work analytically then substitute numbers)

- Make an estimate for the average kinetic energy of the hydrogen atom in the well and estimate the velocity of the H. Compare these estimates to the kinetic energy and velocities of an electron in a Bhor orbit (Hint. $\beta = \alpha$, Hmmm, maybe I better add the Bohr model formulas to the formula sheet.)

- Write down the all the levels which are degenerate with $3s$ state of hydrogen. (You do not have to bother yourself with spin in this problem. Just let me know if you are doing this problem with or without spin)
- Write down the $2p$ hydrogen wave function and verify that it is correctly normalized.
- Make a qualitative sketch for the $2p$ wave function and also the associated probability.
- Determine the most likely position to find the electron in the $2p$ state.
- Make an estimate for the kinetic energies and compare your results to the Bohr model for $n = 2$. (Again, maybe I better add the Bohr model formulas) ;