PHY 3107, Spring 2016, Homework #3

due Friday, Jan. 29, at 12:00 pm (noon)

1.) It has been suggested that the neutron could be considered to be a bound state of the proton and electron. In that case, the mass of the neutron would be comparable to (or a little less) than the mass of the electron, plus the proton, plus the potential energy between the two of them. Let's play with this. [Hint: it may be useful to think of the mass in units of MeV/c^2, and use the constant $\hbar c = 197\ MeV - fm$.

a) Consider the mass difference between the proton and neutron. What is it in units of MeV/c^2? b) Treating the electron as a particle in a 3-dimensional, cubical box of side 1 femtometer (fm), calculate the ground state energy of an electron in such a box in units of MeV. c) OK, now let's put it all together: is the mass difference between the neutron and proton comparable to the mass of the electron and the energy of confining it to such a small box?

2.) An electron is confined to a quantum dot. If the transition between states with the lowest energy gives off a photon of wavelength 400 nm, what is the size of the quantum dot (e.g., the length of a side of a cubical box containing the electron)?

3.) A helium atom in an excited state is trapped in a cubical box of side L. The wavefunction is given by $\psi(x,y,z) = \left(\frac{2}{L}\right)^{3/2} \sin\frac{2\pi x}{L} \sin\frac{\pi y}{L} \sin\frac{2\pi z}{L}$. Calculate the probability of finding the atom in the region $\frac{L}{3} < x < \frac{2L}{3}, \frac{L}{3} < y < \frac{2L}{3}, 0 < z < \frac{L}{2}$.

4.) A particle is orbiting due to an attractive central force. If it has an angular momentum of 1.00×10^{-33} kg m/s, what are all of the possible *z*-components of angular momentum that can be detected?

5.) At the CERN LHC, two beams of protons move in a circle of circumference 27 km, with energies upto 7 TeV (a TeV is 10^{12} eV; the protons are ultrarelativistic). A) Find the orbital angular momentum of the proton. B) What is the orbiatal angular-momentum quantum number for a proton?