

PHY 3107, Spring 2017, Homework #3

due Tuesday, Jan. 31

- 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 $\hbar c = 197 \text{ MeV} \cdot \text{fm}$.
 - 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 500 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 $1.00 \times 10^{-33} \text{ kg m/s}$, 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 and you need to use).
 - A) Find the orbital angular momentum of the proton.
 - B) What is the orbital angular-momentum quantum number for a proton?