Name(s): PHY-222 (Fall 2017), 10/26/17

Homework Assignment #5

(*Due Date*: Thu, 11/02, 05:30 pm, in class; Show all your work for full/partial credit)

5.1 *Matter Waves* (cf. Prob. 5.5 in textbook) *(5 pt.)*
To study small objects, one needs probes with a resolution (*i.e.*, wavelength) comparable to the size of that object. Find the appropriate kinetic energies (in eV) of electron beams ($m_e c^2$=511 keV) and neutron beams ($m_n c^2$=940 MeV) to probe

(a) organic molecules of size 10 nm;

(b) atomic structures of size 1$\mathring{A}$;

(c) the structure of the proton at sizes below 1 fm.

(d) Compare the electron's kinetic energy in (b) to the kinetic energy of an electron in the ground state of the Bohr hydrogen atom. Quantitatively account for the mismatch, if any.

(e) Suppose the electron were in a hydrogen orbit of radius 10 fm. Compare its kinetic energy obtained from the Coulomb binding (virial theorem) to that it would have if you fit that electron's wavelength on this orbit.

5.2 *Heisenberg Uncertainty Principle* (cf. Probs. 5.19+20 in textbook) *(4 pts.)*

(a) A proton has a kinetic energy of about 20 MeV. If the pertinent momentum has been determined with an accuracy of 1%, what is the minimal uncertainty in determining its position? Compare this to the size of the proton.

(b) The wavelength of a photon has been measured at 400 nm with an accuracy of 2ppm (parts per million). What is the minimum uncertainty in a position measurement of this photon? Compare this to the photon's wavelength.

5.3 *Decay Width and Lifetime of Unstable Particles* (cf. Quest. 5.26 in textbook) *(1 pts.)*
The ρ-meson is a short-lived particle (with an average mass of m_ρ=770MeV/c^2) that can be produced in particle accelerator experiments. It can only be detected through its decay products, typically 2 pions. From the energies and momenta of the two decay pions, the mass of the ρ meson can be reconstructed, as schematically shown in the graph below. From the uncertainty in the mass (or spectral) distribution of the ρ line shape, estimate the lifetime of the ρ meson (in seconds), by using the full-width-half-maximum of the resonance as a measure of the energy uncertainty.