QUANTUM MECHANICS III

PHYS 518

Problem Set # 5

Distributed: Nov. 11, 2011

Due: Nov. 18, 2011

1. Point "Renormalization": Assume that a "point" particle of charge q is really highly localized around its centroid and that the charge distribution is given by $q\rho(\mathbf{r}-\mathbf{r_0})$, where $\mathbf{r_0}$ is the location of the centroid and the probability distribution function is spherically symmetric with $\langle(\Delta r)^2\rangle = \frac{3}{4}\lambda^2$.

a. If this particle is in an electric field with potential $V(\mathbf{r})$ determine how the point particle interaction energy $qV(\mathbf{r_0})$ is "renormalized".

b. Show how this changes the nature of the electron interaction with the nucleus in a many-electron atom.

c. Determine how this modifies the electron-electron interaction in a many electron atom.

Assume $\lambda = \frac{\hbar}{mc}$.

2. Dimensional Analysis: Three fundamental constants that determine the nature of most of nongravitational physics are: e (electrodynamics), c (special relativity), and $\hbar$ (quantum mechanics).

a. By eliminating one at a time, construct quantitites with the dimension of length (cm, if you will) from the remaining two. For each of these three products: determine the value (in cm) and provide a clear physical interpretation.

b. Use all three fundamental constants to construct a dimensionless constant. What is the value of this constant? (Using Google is encouraged.)

c. How are the three lengths and the dimensionless constant related?

d. Explain how one of these lengths enters into Problem # 1.

3. Fine Structure:

a. Write down the electronic ground state structure for Si and S.

b. For each ground state configuration write down the multielectron states arising from this configuration.

4. More Fine Structure: Repeat Problem #3 for Ti and Ni.

5. Interferometers: Write a short essay describing how a Ramsey Interferometer is similar to/and different from a Mach-Zehnder Interferometer.