QUANTUM MECHANICS I

PHYS 516

Problem Set # 5

Distributed: February 4, 2013

Due: Feb. 13, 2013

1. Hydrogen Atom: a. Draw the energy level diagram for the hydrogen atom. Pay particular attention to the energy scale and identify states by their principal quantum number N and orbital angular momentum quantum number l. Identify the energy and orbital degeneracy of each state.

b. What deexcitations are possible from the $4p$ level?

c. If the electron transitions to the $2s$ level, what happens?

2. Scaling: Estimate the energy of a μ^- meson around a Pb nucleus. Useful information: $m_\mu/m_e \simeq 207$, $Z = 82$, $E_g = -13.6$ eV.

3. Uncertainty Principle: Use the Uncertainty Principle $\Delta x^2 \Delta p^2 \geq (\hbar/2)^2$ to estimate the ground state energy of the "Planck" harmonic oscillator with Hamiltonian $H = \frac{p^2}{2m} + \frac{1}{2}kx^2$.

4. Crude Classical - Quantum Correspondence: A particle of mass m is placed inside an infinitely deep one dimensional potential well of length L (i.e., between two brick walls).

a. Make a reasonable guess as to its uncertainty in position: Δx^2.

b. On the basis of your guess in **a.** and the Uncertainty Principle, guess its momentum p.

c. Estimate its ground state energy.

d. Compute the force the particle exerts on either wall. Do this by computing: the momentum transfer per collision and the number of collisions per unit time.

e. Compute the amount of work done when the well is slowly compressed from length L to length $\frac{2}{3}L$.

f. What is the final energy of the particle?

g. Compare this energy with the energy you would compute using the expression constructed in part **c.**

5. Dirac Notation: The four most important states of a quantum system have energy $E_i = -1.5, -0.5, 0.5, 1.5$ and wavefunctions ϕ_i in the absence of a perturbing potential. When a particular perturbation is added your computer code emits the following information for energy eigenvalues ϵ_i and eigenstates ψ_i:

	ψ_1	ψ_2	ψ_3	ψ_4
$E:$	-3.270	-0.670	1.428	2.512
$\phi_1:$	0.652	-0.690	-0.174	0.258
$\phi_2:$	-0.666	-0.330	-0.294	0.599
$\phi_3:$	0.358	0.626	-0.133	0.679
$\phi_4:$	-0.037	-0.114	0.930	0.335

a. With the perturbing potential present the particle is in the excited state ψ_3 with energy $\epsilon_3 = 1.428$. The perturbation is suddenly removed. What is the probability amplitude that the particle is in the ground state ϕ_1 with energy -1.5? What is the probability?

b. With no perturbing potential present the particle is in the excited state ϕ_3 with energy $E_3 = 0.5$. The perturbing potential is suddenly applied. What is the probability that the particle is in ψ_1 with energy $\epsilon_1 = -3.270$?