Physics 829 Spring 2001
Dr. Herbst

FINAL EXAMINATION (In Class; Closed Book)
4 JUNE
(150 POINTS)

1. (40 pts) In the theory of the interaction of radiation with matter, consider the $W' = \frac{1}{2m} q^2 A_z^2$ interaction term we neglected in class. Using the semiclassical theory of radiation and first-order time-dependent perturbation theory, determine the absorption probability P_{fi} as a function of ω for the hydrogen atom transition 1s -> 2p if only W' is considered. You need not compute any spatial integrals. Use the term in W' that yields the largest non-zero answer. What is unusual about your expression?
$A_0 = B/\, 2ik$

2. (30 pts) Use the variational method to determine an approximate value for the ground state energy of a particle trapped by the one-dimensional potential:

$$V(x) = k\,|\,x\,|\ .$$

Choose as your trial function a Gaussian: $\psi = \exp(-\alpha x^2)$. How does your result compare with the exact value of $E_0 = 0.8086(k^2\hbar^2 / m)^{1/3}$?

3. (30 pts) Consider a tritium (heavy hydrogen) atom (Z=1) with an electron in its 1s state. The nucleus suddenly undergoes beta decay such that Z=2.

a) (15 points) What is the probability that the electron remains in its 1s state?
b) (15 points) Can you think of a general selection rule for the sudden process?

$$\psi_{1s} = \frac{\sqrt{Z^3}}{\sqrt{\pi a_0^3}} \exp(-Zr / a_0)$$

4. (50 pts) The energy levels of a nucleus can often be expressed in terms of the solutions to the three-dimensional isotropic harmonic oscillator. For one particle, the lowest three energy levels are as follows: 0s ($E = 1.5\hbar\omega$), 1p ($E = 2.5\hbar\omega$), and 2s and 2d, both with $E = 3.5\hbar\omega$.

a) (40 pts) Consider two non-interacting identical spin-1/2 fermions in a nucleus. Determine the energies, degeneracies, term symbols, and suitable kets for the three lowest configurations. Your kets can be determined by use of memory, symmetrizers/antisymmetrizers, or by angular momentum considerations.
b) (10 pts) Do the same problem for the lowest configuration of three non-interacting spin-1/2 fermions.