Midterm Exam # 2
Physics 137B, Spring 2004

PLEASE MAKE SURE YOU WRITE YOUR NAME AND STUDENT ID ON YOUR EXAM.

This exam contains 3 questions, each with multiple parts. You should answer all the questions to the best of your ability. Please show your all work. If you use paper rather than a blue book, make sure you staple all the pages together.

Calculators are not necessary. You may take ONE sheet of $8\frac{1}{2} \times 11$ inch paper with equations into this exam.

DO NOT TURN THE PAGE TO OPEN THIS EXAM UNTIL YOU ARE TOLD TO!!

1. **(25 Points)** Consider three neutrons in a three-dimensional rectangular box of length L in the x and y directions and length $10L$ in the z direction.

   (a) What is the ground state energy of this system?

   (b) What is the value of the total spin of this ground state?

   (c) What is the energy of the first excited state?

   (d) What is the degeneracy of the first excited state?

   (e) For the first excited state, what are the possible value(s) of the total spin?

2. **(15 Points)** In the He atom, the two electrons can be in a singlet or a triplet spin state.

   (a) Why is there no triplet ground state?

   (b) Whis is the excited $1s2s$ state $^1S_0$ lower in energy than the excited $1s2p$ state $^1P_1$?

   (c) Why is the $1s2s$ state $3S_1$ lower in energy than the $1s2s$ state $^1S_0$?

   Your answers to these questions need only be a sentence each. No proof is required

3. **(30 Points)** A particle moves in the one dimensional potential $V(x) = \lambda x^4$. Use a trial function $Ae^{-\alpha x^2/2}$ to find an upper bound on the ground state energy.
   You find the following integrals useful:

$$\int_0^\infty x^{2n} e^{-\beta x^2} dx = \frac{1 \cdot 3 \cdots (2n-1)}{2^{n+1}\beta^n} \frac{\pi}{\beta}^{\frac{1}{2}} \quad (\beta > 0)$$

$$\int_0^\infty e^{-\beta x^2} dx = \frac{1}{2}(\frac{\pi}{\beta})^{\frac{1}{2}} \quad (\beta > 0)$$

4. **(30 Points)** Consider a particle of charge q and mass m which is in a one dimensional simple harmonic oscillator

$$H_0 = \frac{\hbar^2}{2m}\frac{d^2}{dx^2} + \frac{1}{2}kx^2$$

A homogeneous electric field is applied

$$\mathcal{E}(t) = \mathcal{E}_0 e^{-(t/\tau)^2}$$

If the particle is in the ground state ($n = 0$) at time $t = -\infty$, find the probability that it will be in the $n = 1$ state at $t = +\infty$. You may use the find the following integral useful:

$$\int_{-\infty}^{+\infty} e^{-\alpha x^2} e^{-\beta x} dx = (\frac{\pi}{\alpha})^{\frac{1}{2}} e^{\beta^2/2\alpha}$$