PHYSICS 631 Autumn 2005 Midterm #1

Name:____

Do NOT simply write an answer. Give a calculation and/or reasoning that supports your answer.

1) A 3 GeV photon scatters from a mass $=2\ GeV/c^2$ particle initially at rest at an angle $3\pi/2$ (straight down). *Use energy and momentum conservation* to compute: (a) the photon's final energy, (b) the photon's initial and final wavelengths, (c) the electron's final energy, (d) the electron's final momentum. Remember that the momenta are vectors and give both components in (d). Use the approximation $\hbar c = 200\ Mev\ fm$ where $1 fm = 10^{-15} m$. Simplify expressions as far as possible without using a calculator.

2) A single electron is bound to a Helium nucleus which has charge $2e$. Use Bohr's quantization condition, $p_n r_n = n\hbar$, and the fact that for a circular orbit:

$$\frac{mv_n^2}{r_n} = \frac{Z\alpha\hbar c}{r_n^2},$$

where $\alpha = 1/137$ and Z is 2, to compute: (a) r_n, (b) p_n, (c) E_n. Remember that the energy is just the sum of kinetic energy plus Coulomb potential energy. Note that $\alpha\hbar c = e^2/(4\pi\epsilon_0)$. The electron mass is $0.511 MeV/c^2$.

3) A particle of mass m is confined to a "box" in one dimension which goes from $x = 0$ to $x = a$. The energy eigenstates satisfy $\Psi_n(x,t) = \psi_n(x)\, e^{-i\omega_n t}$. For this box $\psi_n(x) = \sqrt{2/a}\, \sin(k_n x)$, where $k_n = n\pi/a$ and the energy is $\hbar\omega_n = \hbar^2 k_n^2/(2m)$. (a) For a particle in the first excited state ($n = 2$), what is the probability of finding the particle in the left half of the box ($0 < x < a/2$)? What are the possible values of momentum that can be found? (b) For a particle in the state $\Psi(x,t) = \frac{1}{\sqrt{2}}\Big[\Psi_1(x,t) + \Psi_4(x,t)\Big]$, compute $< x >$. You do not need to explicitly evaluate integrals that *are not zero*, but if an integral vanishes, state this and drop it from the final answer.