Problem Set #3

Due Monday, March 24 by 5pm to Dickinson 104

Unless otherwise indicated, all problems come from "Quantum Physics: A Fundamental Approach to Modern Physics"

1. Problem 2.5
2. Problem 2.8 (*Hint: By thinking carefully about which units you want to use, you can save yourself a bit of math here.*)
3. Problem 2.15
4. Problem 2.20
5. The Heisenberg Uncertainty Principle applies to photons as well as to material particles. Thus, a photon confined to a very tiny box (size Δx) necessarily has a large uncertainty in momentum and energy (recall that for photons, E=pc) and, hence, a large average energy. Since energy is equivalent to mass, according to $E=mc^2$, a confined photon can create a large gravitational field. If Δx is sufficiently small, the energy density will be sufficiently large to create a black hole. This size Δx is called the Planck length and defines the scale at which gravity and quantum mechanics are inextricably mixed (The goal of string theory is to describe what is happening at these scales).
    a. Using Newtonian physics, show that the escape speed for a star of mass M and radius R is $v_{esc} = \sqrt{2GM/R}$
    b. By equating v_{esc} for a black hole to the speed of light, derive a formula for the Planck length in terms of c, G, and ħ.
    c. Calculate the Planck length and show that the value is fantastically small, on order of 10^{-35} m.
    d. What is the diameter of the proton (~2 fm) in units of Planck lengths?
6. In special conditions, it is possible to measure the energy of a gamma ray photon to 1 part in 10^{15}. For a photon energy of 50 keV, estimate the maximum lifetime that could be determined by a direct measurement of the spread of the photon energy.
7. Problem 2.30 (*Hint on the Note: The wave function being an even function makes finding <x> very easy; you should be able to do it without doing any math. You will have to do the math to find <x^2> for that component of Δx*).
8. Problem 2.31
   Additional Part: In addition to the problem in the book, please make a plot (i.e. using a computer) of the a) wave function and b) the probability distribution as a function of *x* to convince yourself that your derived value of <x> is reasonable. Include the plot with your problem set.
9. Problem 2.35