Phys 3820, Fall 2011
Problem Set #3, Hint-o-licious Hints

1. *Griffiths*, **7.6**

2. *Griffiths*, **7.13** We try a wave function of the form

$$\psi(\mathbf{r}) = Ae^{-br^2}$$

First, show that we must have

$$A = \left(\frac{2b}{\pi}\right)^{3/4}$$

and then evaluate $H\psi$. I got

$$H\psi = \left(\frac{2b}{\pi}\right)^{3/4}\left[-\frac{\hbar^2}{2m}\{-6b + 4b^2r^2\} - \frac{e^2}{4\pi\epsilon_0}\right]e^{-br^2}$$

which will eventually give

$$\langle H\rangle = \left(\frac{2}{\pi}\right)^{3/2}(4\pi)\left\{\frac{3}{16}\frac{\hbar^2}{m}\sqrt{\frac{\pi}{2}}b - \frac{e^2}{4\pi\epsilon_0}\frac{b^{1/2}}{4}\right\}$$

which has a minimal value at

$$b = \frac{8}{9\pi}\frac{\alpha^2m^2c^2}{\hbar^2}$$

Substitute and work out the numbers. I find that the optimal value of $\langle H\rangle$ is

$$\langle H\rangle_{\text{min}} = -11.5 \text{ eV}$$

3. *Griffiths*, **7.19** The basic problem is to go through the whole analysis that led to the equilibrium separation of the H_2^+ ion and show that the distances scale inversely with the mass of the negative particle. The muon has about 200 times the mass of the electron so the result is the equilibrium R is 200 times smaller and that fact makes the muon a useful for getting hydrogen nuclei (of all types) close together.

4. *Griffiths*, **8.4** For U^{238} I find that the KE of the alpha is 4.3 MeV giving a speed of $1.44 \times 10^7 \, \frac{\text{m}}{\text{s}}$. It gives a lifetime of the very rough order of 3×10^{15} yr which is several orders of magnitude to high, but at least it's not "short".

For Po^{212} I find, using the *nuclear* masses from my source, an alpha speed of $1.94 \times 10^7 \, \frac{\text{m}}{\text{s}}$ and a lifetime of 0.75 s, which is way off from the experimental value of microseconds, but again, it is "small".

Maybe you can do better using *atomic* masses for the nuclei. But be sure you know what masses you are using; for differences in masses the elctrons masses are important.

5. *Griffiths*, **8.7** Here, $V(x) = \frac{1}{2}m\omega^2 x^2$. We will use the result of Example 8.4 even though we didn't go through the jive with connection formulae. For a potential well which has smooth sides and where the turning points of the motion are x_1 and x_2, we have

$$\int_{x_1}^{x_2} p(x)\,dx = (n - \tfrac{1}{2})\pi\hbar \quad \text{where} \quad p(x) = \sqrt{2m(E - V(x))}$$

(This formula is also one which would have been *postulated* in the pre–Schrödinger quantum mechanics of the years 1915–1925. The early QM gave some correct results but ultimately led nowhere.)

The integral involves an inverse trig function and ultimately gives the correct answer for the HO energy levels.