Physics 214b-2008 Walter F. Smith Assignment 7

Due: 4 pm Wednesday 3-26-08

Reading: 4.6-4.7, 5.1-5.2

Exercises

All problems are group problems, unless otherwise marked; you are encouraged to work in small groups on these. For the individual problems, you are not allowed to consult any other students, but you may ask me for help.

7A. We have not discussed this in class, but quantum harmonic oscillators can be excited from the ground state to a higher excited state by the absorption of a photon. Spectroscopists quote the energy of the absorbed photon in terms of what they call “wavenumbers”, defined as
\[ \text{(number of wavenumbers)} \equiv \frac{1}{\lambda}, \]
where \( \lambda \) is the wavelength in vacuum of the photon. (Note that physicists use the term “wavenumber” to refer to \( k \equiv \frac{2\pi}{\lambda} \).) The “wavenumbers” used by spectroscopists are always quoted in units of cm\(^{-1}\).

A good example is the vibration of one of the hydrogen atoms in water relative to the oxygen atom. In fact, both the oxygen and the hydrogen move during this vibration, but the hydrogen moves much more, since it is less massive. For simplicity, we’ll assume the oxygen is stationary and only the hydrogen moves. Light which can excite the transition from the ground state for this oscillator to the first excited state is 3652 cm\(^{-1}\) wavenumbers. Show that the spring constant for this oscillator is 786 N/m.

7B. a. Show that \( \psi_1 = A_1 e^{-\frac{m\omega_s x^2}{2\hbar}} \) is the first excited state of the harmonic potential, and find the corresponding energy. *Hint: use Mathematica.*
b. Determine the value of \( A_1 \).
c. Plot this state for the oscillator described in problem 7A.

7C. (individual problem) a. Show that \( \psi_2 = A_2 \left(1 - \frac{2m\omega_s}{\hbar} x^2 \right) e^{-\frac{m\omega_s x^2}{2\hbar}} \) is the second excited state of the harmonic potential, and find the corresponding energy. *Hint: use Mathematica.*
b. Determine the value of \( A_2 \).
c. Plot this state for the oscillator described in problem 7A.

4.10 *Hint: Within the well, the physics is the same as for a harmonic potential; only the boundary conditions are different.*

4.14 (individual problem)

4.20 Part b only

4.22

4.28 parts a and b only