

AST 393F
Assignment 2

Due Friday 9/11

1. Consider a particle of mass m moving in a one-dimensional harmonic oscillator potential, $V(x) = \frac{1}{2} kx^2$. You should know the energy eigenvalues, and you can look up the wavefunctions in many QM texts.
 - a) Make a sketch of the wavefunction of the $v = 0$ ground state. How does this wavefunction evolve with time? Is this what you would expect for a harmonic oscillator?
 - b) Make a sketch of the wavefunction of the $v = 1$ state. How does this wavefunction evolve with time? Is this what you would expect for a harmonic oscillator?
 - c) Consider a state that is a linear combination of the $v = 0$ and the $v = 1$ states. Sketch and/or describe this wavefunction at time $t = 0$, $t = \pi/2\omega$, $t = \pi/\omega$, $t = 3\pi/2\omega$, and $t = 2\pi/\omega$.
 - d) How do $\langle x \rangle$ and $\langle p \rangle$ behave with time? (You could calculate the expectation values of these operators. Or you could just look at the wavefunctions and argue qualitatively how they behave.)
 - e) Does this linear combination state behave more like you would expect for a harmonic oscillator?
2.
 - a) Write out the Bohr model derivation of the Rydberg formula, assuming circular orbits with angular momentum quantized in units of \hbar . You can find this in lots of texts, but try it without using the texts so you remember it. Note the dependence of the formula on various quantities and ask yourself why the formula came out the way it did. (Use cgs units, so $V(r) = -e^2/r$.)
 - b) Look up the fundamental constants in your formula, and calculate the value of the Rydberg. (Keep at least 5 digits, and make sure you use the reduced mass of the electron in a hydrogen atom.) You could check your answer by looking up R_H .
 - c) Using your value of R_H , calculate the wavelength of $H\alpha$. Look up the wavelength of $H\alpha$ in a table of wavelengths in Peridier. I suspect the tabulated value will differ from yours by more than the uncertainty in your numbers. Why?
3.
 - a) Write out the derivation of the energy levels of a diatomic molecule, starting with the quantum formula for the square of the angular momentum and the classical formula for the dependence of energy on angular momentum. Use the formula involving the reduced mass and the total angular momentum of the molecule. Note the dependence on various quantities in your formula.
 - b) Look up the internuclear spacing of the CO molecule (in a book by Herzberg). From that and other known constants, calculate the energies of the rotational levels of CO.
 - c) Calculate the wavelengths and frequencies of the lowest few rotational transitions ($J+1 \rightarrow J$) of CO. Compare your numbers with tabulated numbers.