

Homework 5, Due March 4

1. Using the lowering/raising operators for the harmonic oscillator to calculate the following matrix elements:

$$\langle \nu | \hat{x} | \nu + 1 \rangle, \quad \langle \nu | \hat{p} | \nu \rangle, \quad \langle \nu | \hat{x}^2 | \nu \rangle.$$

2. Using the materials taught in the class, show the proportional coefficients in the following expression is correct:

$$\hat{b}^+ | \nu \rangle = \sqrt{\nu + 1} | \nu + 1 \rangle$$

3. Normalize the wave function $e^{-r/a} \sin \theta \cos \phi$ in the spherical coordinates.

4. The gap between adjacent lines in the rotational spectrum of $^{12}\text{C}^{16}\text{O}$ is 3.86 cm^{-1} , calculate the internuclear distance of this molecule.

5. Show that the rotational wavefunction $3 \cos^2 \theta - 1$ is an eigenfunction of the Hamiltonian for a three dimensional rigid rotor. Determine the corresponding eigenvalue.