

**Physics 4410**  
**Quantum Mechanics 2**

**Lecture 5**

**Harmonic oscillator: wave functions**

September 2, 2020

1. Review the quantum harmonic oscillator and its solution.

**Activity 1:** A harmonic oscillator is in the initial state

$$|\psi(0)\rangle = \frac{1}{\sqrt{3}}|2\rangle + \sqrt{\frac{2}{3}}|3\rangle.$$

**(a)** What is  $|\psi(t)\rangle$ ?

**(b)** What is  $\langle \psi(t) | x | \psi(t) \rangle$ ?

2. Determine the ground state wave function  $\psi_0(x) = \langle x|0\rangle$ .

**3.** In general,  $\psi_n(x) = \langle x|n\rangle$  can be written as

$$\psi_n(x) = \frac{1}{\sqrt{2^n n! \pi^{1/4}}} H_n(x) e^{-x^2/2}$$

## Activity 2: Molecular spectroscopy.

The harmonic oscillator can be a good toy model for a chemical bond.

- (a) What wavelength(s) of light might an oscillator of frequency  $\omega$  absorb?

- (b)** The molecule HCl absorbs light at the following infrared wavelengths. Estimate the frequency  $\omega$  of the chemical bond. Is there any disagreement between the data and our toy model? Note that  $c \approx 3 \times 10^8$  m/s and  $\hbar \approx 10^{-34}$  J · s.

$\lambda$ (nm)
746
915
1198
1764
3465