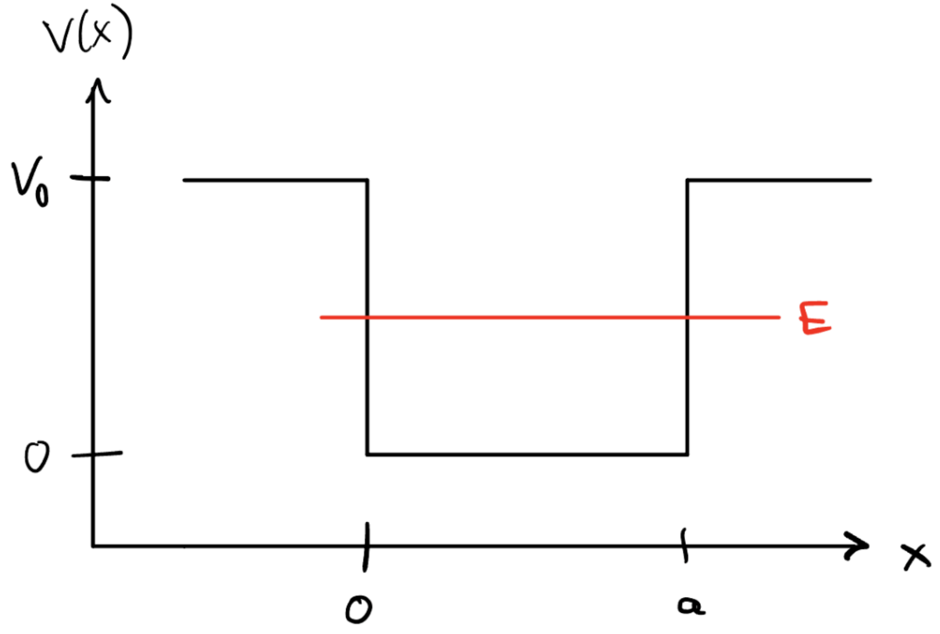
Which of the following statements are correct about a particle **<u>with E < V_0</u>** interacting with the finite box shown in the plot below? **Select all that apply.**



A. The particle's wavefunction is zero outside the box.
B. The particle's wavefunction must be normalizable.
C. The particle is in a bound state.
D. The particle is in an unbound state.
E. The particle has discrete allowed energies.

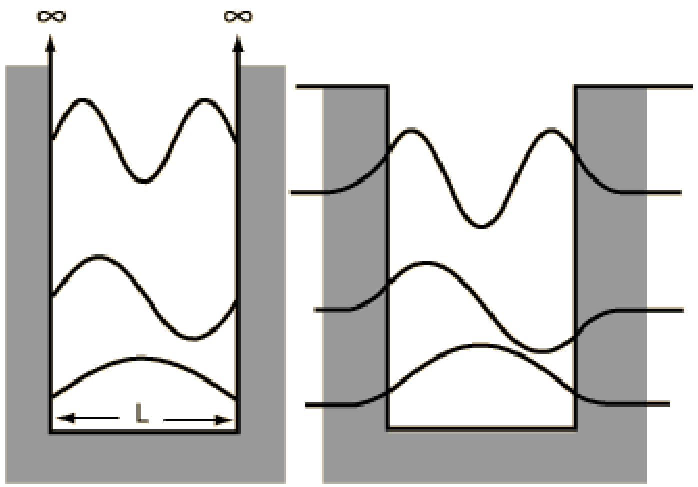
CHM 305 The Quantum World

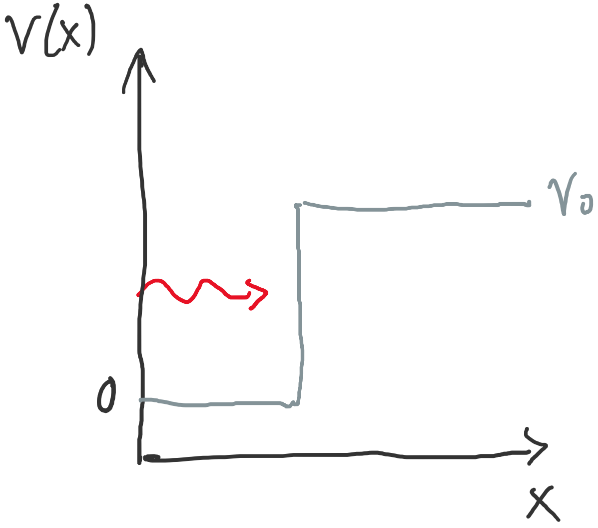
Lecture 8: The Uncertainty Principle

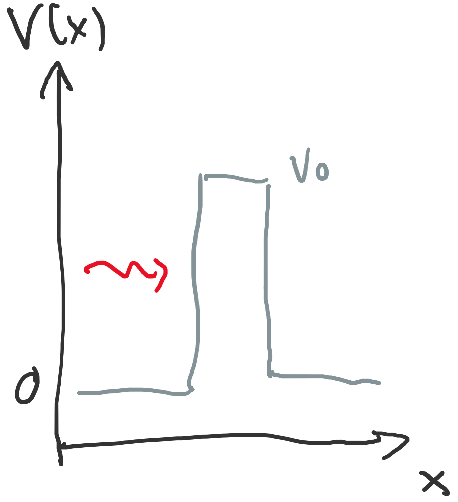
Last lecture…

We found wavefunction solutions for several problems involving potentials with finite walls

- Particle in a finite box
- Particle hitting a finite step
- Particle tunneling through a finite barrier
- How quantum tunneling is important to chemistry

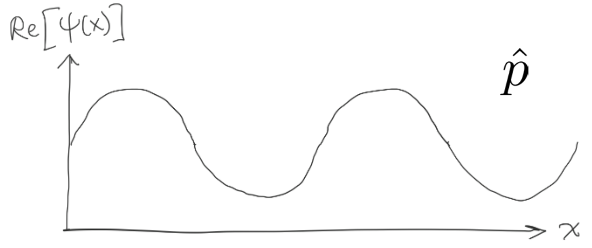




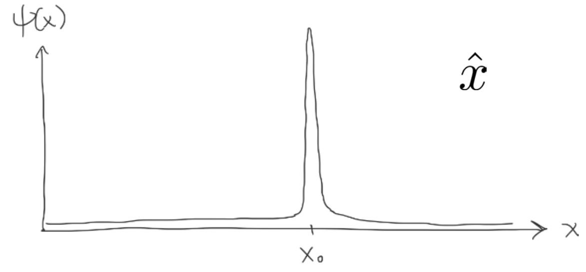


Road map for today's lecture…

- Review the rules for quantum measurements and learn about "wavefunction collapse"



- Discuss trade-offs in uncertainty between knowing a free particle's (or a wave's) momentum and position



- Introduce the variance and standard deviation as metrics for the uncertainty of a measurement

$$\sigma_A^2 = \langle A^2 \rangle - \langle A \rangle^2$$

- Introduce Heisenberg's uncertainty principle

- Discuss resulting consequences for operators that do and do not commute

$$\sigma_A^2 \sigma_B^2 \geq -\frac{1}{4}\left(\int \psi^* \, [\hat{A}, \hat{B}] \, \psi \, dx \right)^2$$

Practice Problem #1: Uncertainty Principle

Apply the uncertainty principle

$$\sigma_A^2 \sigma_B^2 \geq -\frac{1}{4}\left(\int \psi^* \, [\hat{A}, \hat{B}] \, \psi \, dx \right)^2$$

to simultaneous measurements made with the $\hat{x} = x$ and $\hat{p} = -i\hbar \frac{d}{dx}$ quantum operators, and find an expression for $\sigma_x \sigma_p$.

Practice Problem #2: Commuting Operators

For a free particle, $V(x) = 0$ and therefore the Hamiltonian is just the kinetic energy operator

$$\hat{H} = -\frac{\hbar^2}{2m}\frac{d^2}{dx^2}$$

Does the momentum operator $\hat{p} = -i\hbar\frac{d}{dx}$ commute with this Hamiltonian?

What does this imply about the eigenfunctions of these two operators?