1. Using raising and lowering operators efficiently

Find the expectation value of the potential energy in the nth state of the harmonic oscillator. Start with the following expression and use ladder operators to simplify the derivation.

$$\langle V \rangle = \langle \frac{1}{2} m\omega^2 x^2 \rangle$$

$$x = \sqrt{\frac{\hbar}{2m\omega}} (\hat{a}_+ + \hat{a}_-)$$

2. <u>The Hamiltonian-Position commutator</u>

Show that

$$[\hat{H}, \hat{x}] = \frac{-i\hbar}{m}\hat{p}$$

You may assume that the potential energy is only a function of position, $V(x)$.

3. **Finite well with a modification**

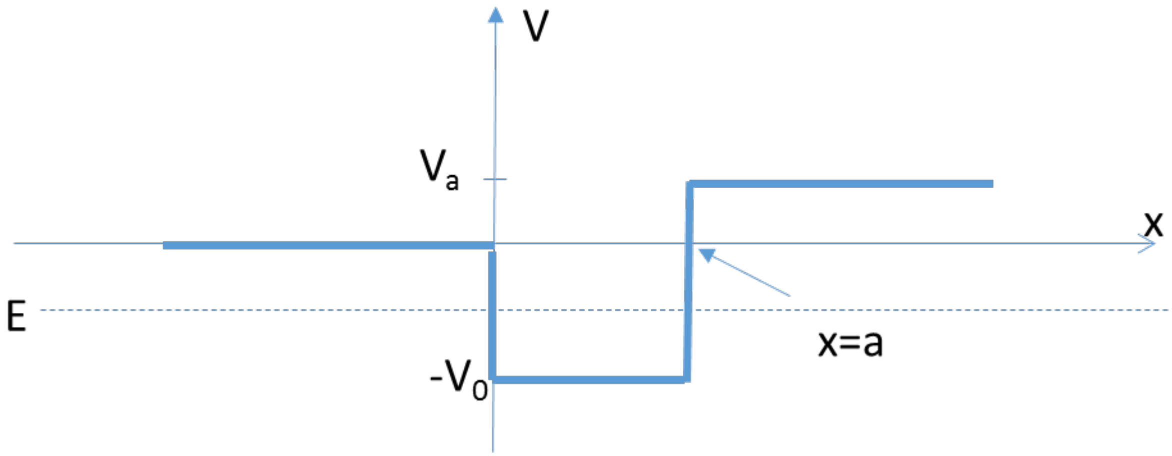
Consider a finite square well of width a and having depth V_0.

a) Sketch the potential well.

b) What must the particle energy E be in order to obtain bound states?

c) Write the general solution to $\psi(x)$ for the particle? (Note: (d) and (e) are on the next page.)

Consider now the asymmetric well (as shown below).



d) What are the **general** solutions $\psi(x)$ for each of the three regions $\begin{matrix} x < 0 \\ 0 < x < a \\ x > a \end{matrix}$?

e) Use the boundary conditions to obtain values for the coefficients and then write the particular solutions.