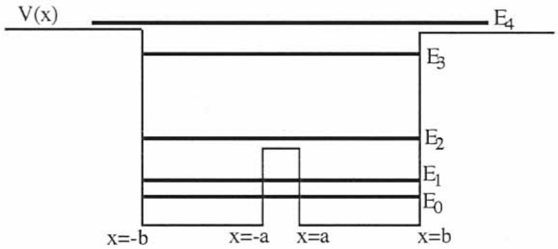
S4. The energy levels E_n of a symmetric potential well V(x) are denoted below.

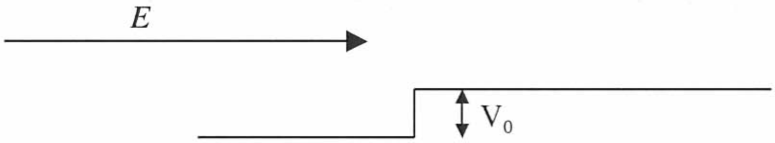


(a) How many bound states are there?

(b) Sketch the wave functions for the first three levels (n=0,1,2). For each, denote the regions where the particle is classically forbidden.

(c) Describe the evolution of the wave function if we start in an equal superposition of eigenstates n=0 and n=1.

S5. A particle with well defined energy E is scattered from a one dimensional step potential of height V_0. What is the probability of reflection when $E < V_0$ and $E > V_0$.



<u>Long Answers: Pick two out of three problems below</u>

L1. A harmonically bound particle experiences a constant force F.

(a) Argue that the interaction Hamiltonian associated with this force is $\hat{H}_{\text{int}} = -F\hat{x}$.

(b) Assuming the force is weak compared to the harmonic binding. Show that the lowest nonvanishing perturbation to the energy of the n^{th} bound state is

$$\Delta E_n = -\frac{(Fx_0)^2}{\hbar\omega}, \text{ where } x_0 = \sqrt{\frac{\hbar}{2m\omega}}$$

independent of level. Hint: Recall $\hat{x} = x_0(\hat{a} + \hat{a}^\dagger)$, where $\hat{a}^\dagger, \hat{a}$ are the creation, annihilation operators.

(c) This problem can be solved exactly, without resorting to perturbation theory. Solve for the exact energy eigenstates and eigenvalues including the harmonic potential and perturbing force.

(d) Show that your exact energy spectrum agrees with the perturbation result to the appropriate order in the perturbation's small parameter.