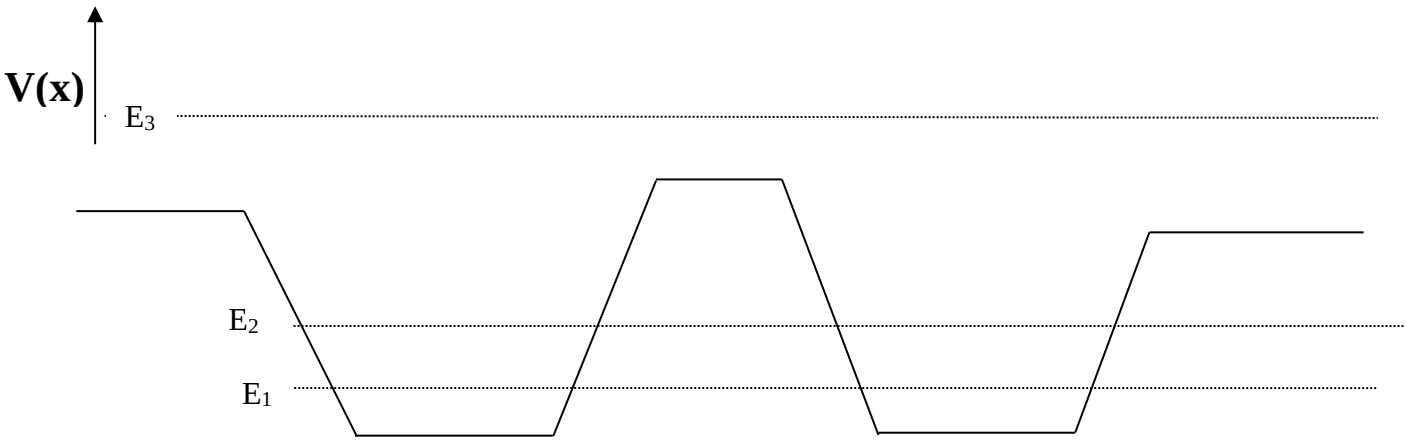
Homework #2

CHMY 564
17jan19 Due Wed., Jan. 23

1. For the one-dimensional potential for a particle below, draw *qualitatively* the 3 lowest energy well-behaved energy eigenfunctions separately on the abscissas provided below. For full credit, the sign of the curvature must be correct at all points, as prescribed by the respective energy eigenvalues of these states shown by the dotted lines. In addition, other general aspects associated with the lowest 3 energy eigenfunctions of any system should be apparent in your drawing. **Point out regions of tunneling, if any.**



$\Psi_{3(x)}$ 0

$\Psi_{2(x)}$ 0

$\Psi_{1(x)}$ 0

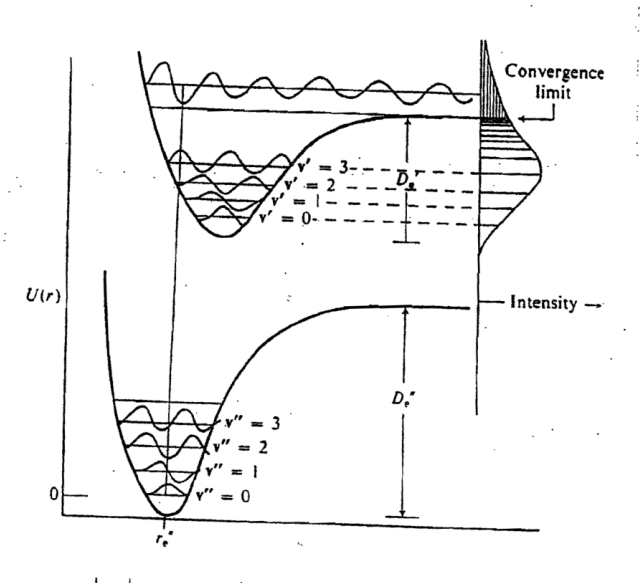
2. (a) For the electron in the H atom 1s state, determine if there exists tunneling by two different means:

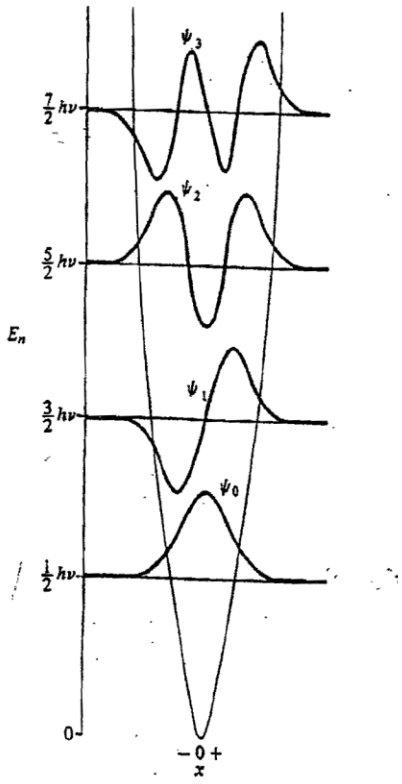
1) Using the expression for the curvature in spherical coordinates (which is simple for the 1s orbital), determine if there is a region for which the curvature indicates tunneling.

2) Use the virial theorem to see if there is a region for which kinetic energy, T(r), will have T(r) is less than 0. (Note that $\boldsymbol{H}$ R(r) = E(r) R(r) = $\boldsymbol{T}$ R(r) + V(r)R(r) $\boldsymbol{H}$ R(r)/ R(r) = E(r) = ($\boldsymbol{T}$ R(r))/ R(r)) + V(r) , suggests that the virial theorem is valid for all positions of the electron wave function.

(b) For the 1s electron in the Be^{+3} ion, V(r) = -4/r in atomic units, and Ψ is proportional to exp(-4r/a_0), where a_0 = bohr radius =1 a.u. . Using either of the methods in (a), determine if a significant amount of tunneling occurs for the electron? If your answer is yes, in what region of space is the electron tunneling?

3. (a) Depictions shown on figures above taken from some textbooks may be criticized. Are all





the harmonic oscillator wavefunctions in the figures on this page correctly drawn in terms of curvature? If not, point out which ones are incorrect in detail, and explain what is incorrect. Point out which ones appear correct, if any.

(b) Provide correctly drawn functions for the lowest 3 levels of a harmonic oscillator.

4. Give a short opinion based on your experience so far about the validity of the following statement: **Tunneling is present for ALL quantum states of systems bound by a *finite* potential?**
(If you can find this statement in any source (including Wikipedia), please cite it.)