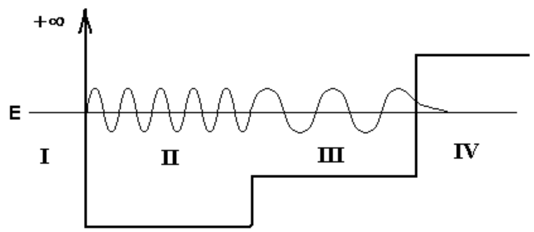
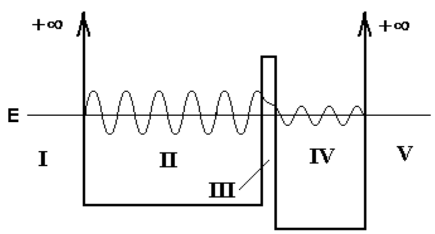
"Psi's Does Matter" (50,000 points)

1.) In the following diagrams (a) and (b), the wavefunction for a particle with energy E is shown. Sketch in a potential energy U(x) which should generate the wavefunction shown. Identify with Roman Numerals (I, II, III, etc.) each region with a particular U(x) that requires a separate solution. (Essentially this problem is the reverse of those in the Sample Exams…) *PLEASE NOTE: Windows Paintbrush draws lousy sine curves!*

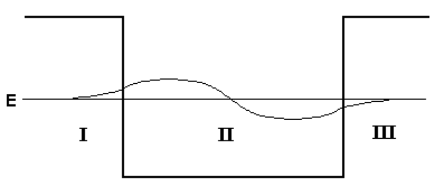
(a)



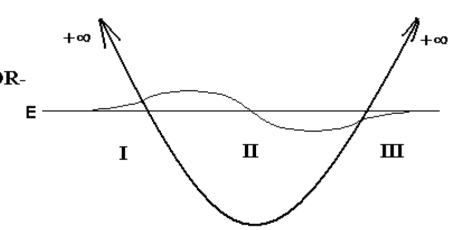
(b)



(c)



-OR-

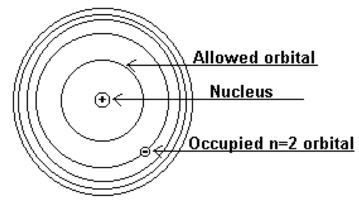


(d) For the problem in (c), write down the quantum number *n* of the state shown for your choice of potential.

For both case, the wave shows a node in the middle, so this is the second state.

For the Finite Well on the LEFT	For the Quantum Harmonic Oscillator on the RIGHT
n = 2	*n = 1 (because we start with n=0)*

(e) The following illustration was drawn to show allowed circular orbits in the Bohr hydrogen atom. What's wrong with this picture? *Short answer, please.*



The allowed Bohr orbitals for the hydrogen atom (and the hydrogenic ions) have a radius given by:

$$r_n = \frac{n^2}{Z} a_0$$

So the distance between orbitals should be getting LARGER, not SMALLER.

(However, this ends up taking up a lot of space, which is why the illustrations have been kept.)

"*Take Your Zinc and Avoid Getting A Spring Cold*" (50,000 points)

2.) (a) A Zinc atom, Z = 30, has 30 electrons. Write down the electronic configuration of the ground state. (Starts with $1s^2$…)

30
Zn
Zinc
65.39

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$

(b) The last electron to be added to the ground state closes the 3d sub-shell. Identify by letter and value the four quantum numbers of this last electron.

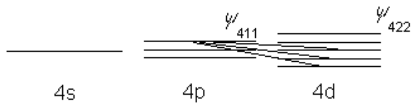
n = 3 l = 2 m = -2 $m_s = -½$

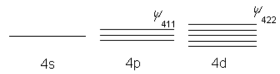
(c) For a hydrogenic zinc ion, Zn^{+29}, find the energy E_3 and radius r_3 of an $n = 3$ electron.

$$r_n = \frac{n^2}{Z} a_0 = \frac{3^2}{30}(0.529Å) = 0.1587Å$$

$$E_n = -\frac{Z^2}{n^2}(13.6eV) = -\frac{30^2}{3^2}(13.6eV) = -1360eV$$

(d) For the QM hydrogen atom, there are no transitions between 4p and 4d under normal circumstances, because they are degenerate in energy. If we have Zeeman splitting due to an applied magnetic field B, identify which 4d states the 4p state ψ_{411} can drop down to, emitting a photon:





There are three allowed transitions:

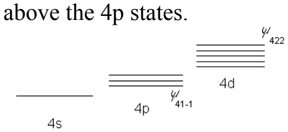
$$\psi_{411} \rightarrow \psi_{420}$$

$$\psi_{411} \rightarrow \psi_{42-1}$$

$$\psi_{411} \rightarrow \psi_{42-2}$$

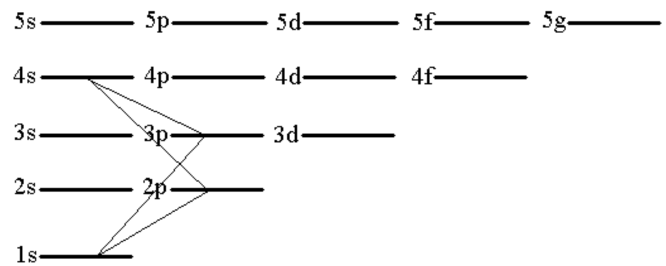
Repeat this for the general QM atom with Zeeman splitting.

There are *NO* allowed transitions, because all of the 4d states are above the 4p states.



(e) Identify and count all the allowed 4s $\rightarrow$ 1s pathways for:

(1) Hydrogen – with the $\Delta l = \pm 1$ Selection Rule

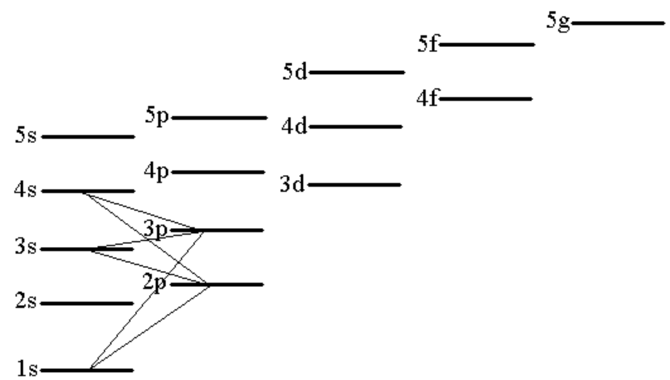


With the Selection Rule, there are only two spin-up pathways:

4s → 3p → 1s (degeneracy = 1 × 3 × 1 = 3)

4s → 2p → 1s (degeneracy = 1 × 3 × 1 = 3)

and (2) the Multielectron Atom – with the $\Delta l = \pm 1$ Selection Rule



With the Selection Rule, there are now three spin-up pathways:

4s → 3p → 3s → 2p → 1s (degeneracy = 1 × 3 × 1 × 3 × 1 = 9)

4s → 3p → 1s (degeneracy = 1 × 3 × 1 = 3)

4s → 2p → 1s (degeneracy = 1 × 3 × 1 = 3)