Name: **Hydrogen Atomic Orbitals Assessment**

1. Determine how many different orbitals can correspond to the given quantum numbers.

   (a) $n = 1$, $l = 0$ **1**

   (b) $n = 2$, $l = 1$ **3**

   (c) $n = 3$, $l = 1$ **3**

   (d) $n = 3$, $l = 2$ **5**

   (e) $n = 3$, $l = 2$, $m = -1$ **1**

   Solution:
   The general result used here is that since m ranges from $-l$ up to l, there are a total of $2l + 1$ different values of m that match up with a given set of n and l quantum numbers. For one specific value of m there is only one orbital.

2. The wavefunctions for a hydrogen atom are labeled with three quantum numbers n, l, and m in the form $\phi_{n,l,m}$, where m is also sometimes called m_l.

   (a) How many total nodes are there for the wavefunction $\phi_{2,1,1}$? **1**

   (b) How many angular nodes are there for a wavefunction $\phi_{2,1,1}$? **1**

   (c) How many radial nodes are there for a wavefunction $\phi_{2,1,1}$? **0**

   (d) How many total nodes are there for the wavefunction $\phi_{4,2,0}$? **3**

   (e) How many angular nodes are there for a wavefunction $\phi_{4,2,0}$? **2**

   (f) How many radial nodes are there for a wavefunction $\phi_{4,2,0}$? **1**

3. Which of the quantum numbers n, l, or m or some combination of these quantum numbers determine the energies of the orbitals for a hydrogen atom without an applied electromagnetic field?

   Solution:
   The quantum number n is the only quantum number that determines the energies of a hydrogen atom orbital (outside of a magnetic field). This is shown via the Rydberg formula,

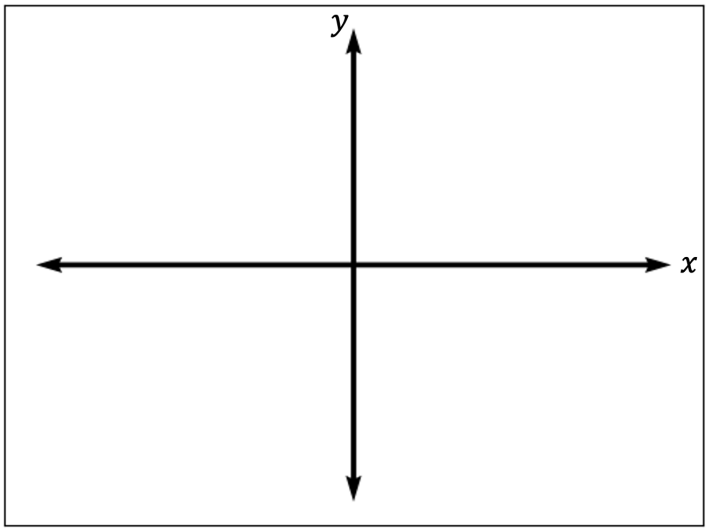
   $$E_n = -\frac{R_H}{n^2}$$

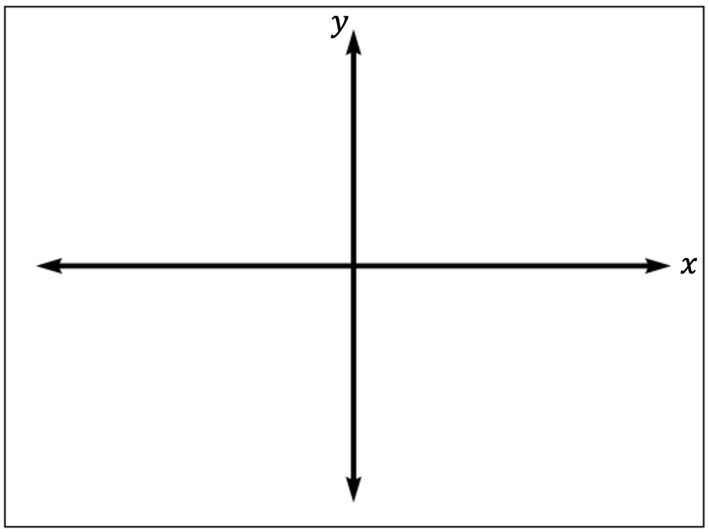
4. What quantum number(s) can be used to determine how many nodal planes are perpendicular to the $x-y$ plane?

Solution:

The quantum number m tells how many nodal planes are perpendicular to the $x-y$ plane.

5. On the following coordinate axes, draw a projection of the hydrogen wavefunctions $\phi_{n,l,m}$ with the quantum numbers $n=2$, $l=1$ and $m=\pm 1$ (the $2p_x$ and $2p_y$ orbitals). Be sure to indicate regions of differing phase.





Solution:

The requested orbitals are shaped like dumbbells oriented along either the x or the y axes. There are no radial nodes and the lobes on opposite sides of the axis have opposite sign. This is shown in the diagrams below.