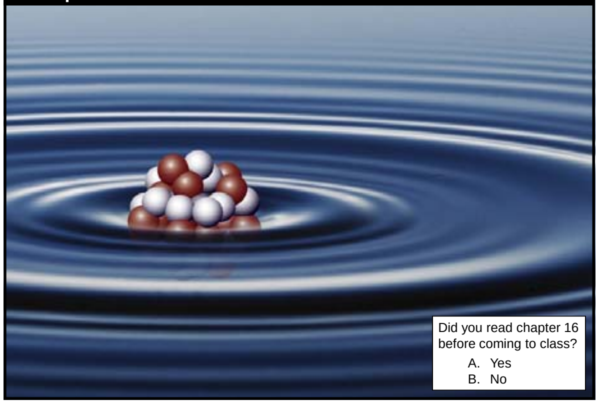
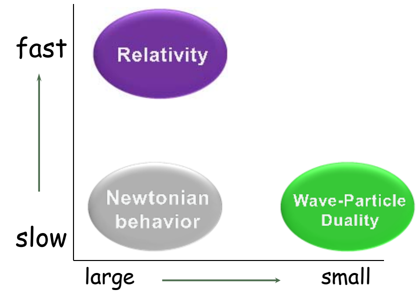
Chapter 16: The wave model of the atom

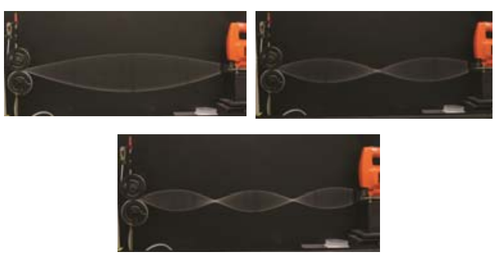


Where do different theories apply?

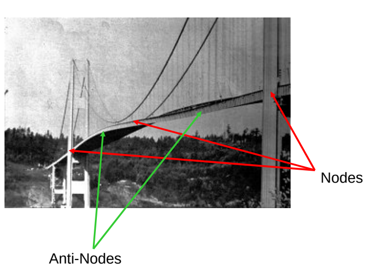


Waves that stay in one place: Standing Waves

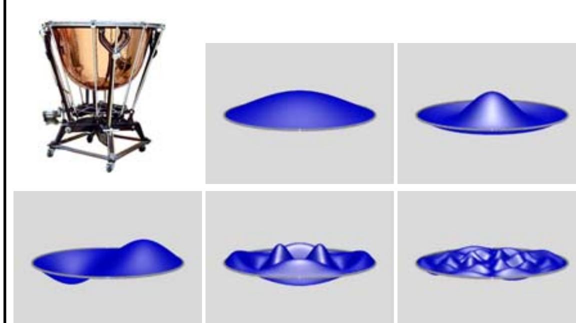
- We can create one dimensional standing waves using a rope



The Tacoma narrows bridge



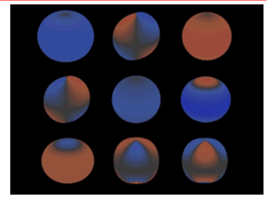
Standing wave modes in two dimensions

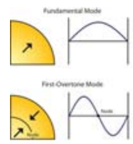


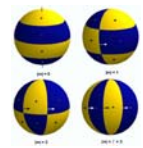
Standing wave modes in two dimensions

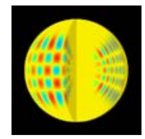
Higher Dimensions

- Standing waves are possible in higher dimension, and can have complicated shapes. Different standing wave shapes are called "Modes".
- In three dimensions you can also get standing waves
  - Singing in the shower
  - Stars vibrating









Standing wave summary

- Standing waves form when a wave is confined
- They are naturally "quantized" in frequency
- They can have complex 1, 2, or 3 dimensional structure depending on how they are confined

Standing surface wave pattern in a cup. The waves confined by gravity and the edges of the cup.

What is the current understanding of what "waves" when a particle acts like a wave?

a) The particle's mass is extended through space and waves
b) The probability of finding a particle in a given place is spread out and waves
c) There is aluminiferous ether spread throughout space that waves

The uncertainty principal states that

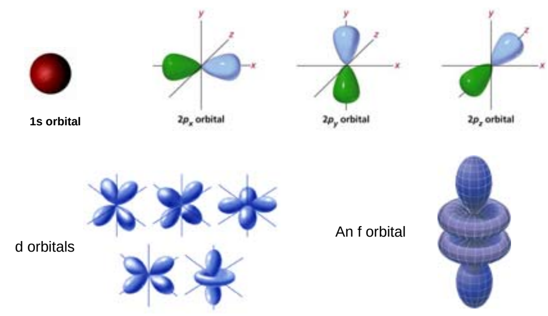
a) We can't know exactly where a particle is
b) We can't know exactly what a particles velocity is
c) We can't know exactly where a particle is and what is velocity is at the same time
d) Scientists are kind of unsure about what they are doing

Since each wavelength represents a different momentum, an unconfined traveling wave packet tends to spread out.

The Wave Model of the Atom

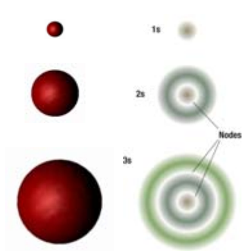
- The wave-particle duality of the electron requires us to treat electrons as waves as long as we aren't "looking" at them.
- A 3-D electron standing ***probability*** wave surrounds the nucleus.
  - We think of the wave amplitude as representing the *probability* of measuring an electron to be located at each point in space.
- Because of the wave nature of electrons, we ***cannot*** know how they move around atoms.
  - An electrons in an atom has a very well-defined positions (i.e. atoms are small), so we can't know about its velocity (momentum).
- We thus call these standing-wave probability distributions ***orbitals*** to reflect the idea that we cannot trace their movement like we can in an orbit (where a particle travels along a specific path).

Orbitals are three dimensional standing probability waves (found by solving the Shrödinger Wave equation)



Visualizing orbitals can be tricky because they are 3-d entities with structure inside.

- We often just draw an outer "surface" that represents the general shape.



http://winter.group.shef.ac.uk/orbitron/AOs/1s/index.html

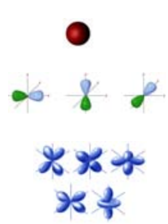
Orbital Patterns

- The orbital types are labeled on as s, p, d, f, g, h, i, j, etc.
- Each new orbital type has two more orbitals than the previous one.
- Each orbital represents a standing wave pattern that an electron probability wave could take on.

Orbital Type	s	p	d	f	g	h	i	j
Orbitals of type	1	3	5	7	9	11	13	15
Electron Capacity	2	6	10	14	18	22	26	30

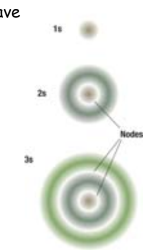
Orbitals come in "shells"

- The first shell contains only an s-orbital
- The second shell contains an s-orbital and 3 p-orbitals
- The third shell contains an s-orbital, 3 p-orbitals, and 5 d-orbitals
- Etc.



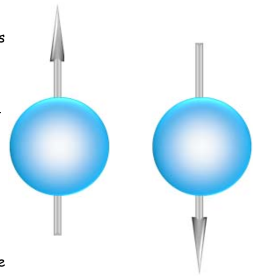
More on shells

- Higher numbered shells are farther from the nucleus.
  - Electrons in higher shells therefore have more potential energy.
- The orbitals in higher numbered shells have more nodes.



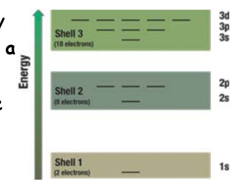
Spin

- Electrons (and other particles) have a property called "spin", just as they have a property called "charge".
- Spin describes the magnetic properties of the electron
  - An electron is sort of like a tiny magnet with a north and south pole.
- When we measure spin, we can only get one of two values:
  - Spin up (the electron's magnet was aligned with our measurement)
  - Spin down (the electron's magnet was aligned opposite our measurement)
- Although we call this spin, it does not describe mechanical spinning of the electron. (As best we can measure, the electron has no physical extent)



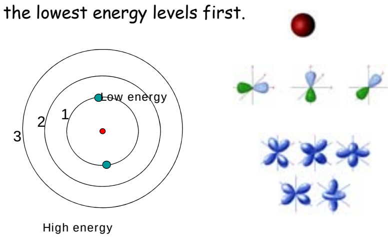
The Pauli Exclusion Principle

- No more than **two** electrons can occupy the **same orbital** (**in a given shell).**
- If two electrons are in the same orbital, they must have **different spins**.



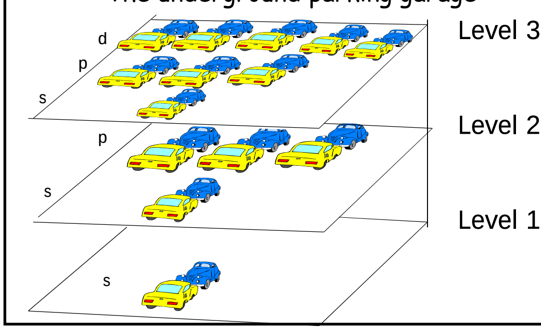
Understanding Atoms

- How do electrons fill the orbitals as we move along the periodic table?
  - Electrons fill the lowest energy levels first.

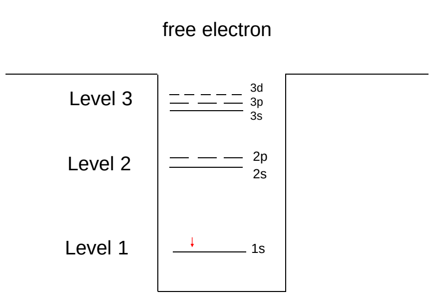


Electron energies - analogy

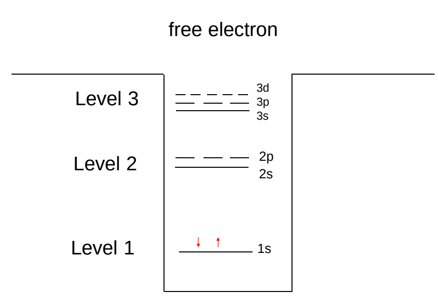
- The underground parking garage



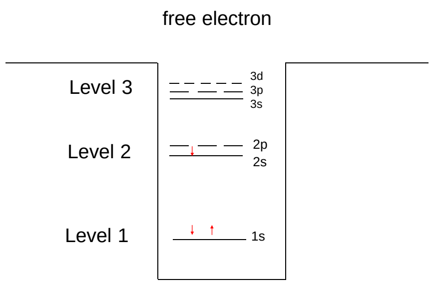
Hydrogen



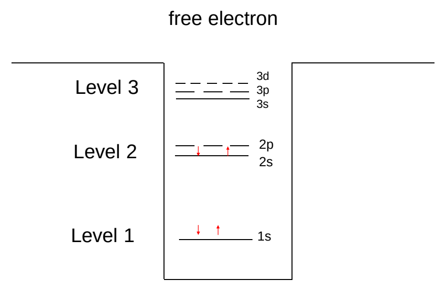
Helium



Lithium



Beryllium



Review

- How many p electrons can there be in a shell?
- Which orbitals are in third shell?
- How many electrons are in an atom that has both the first and second shells filled?