A Little Modern Physics

"Modern" physics means physics discovered after 1900; i.e. twentieth-century physics.

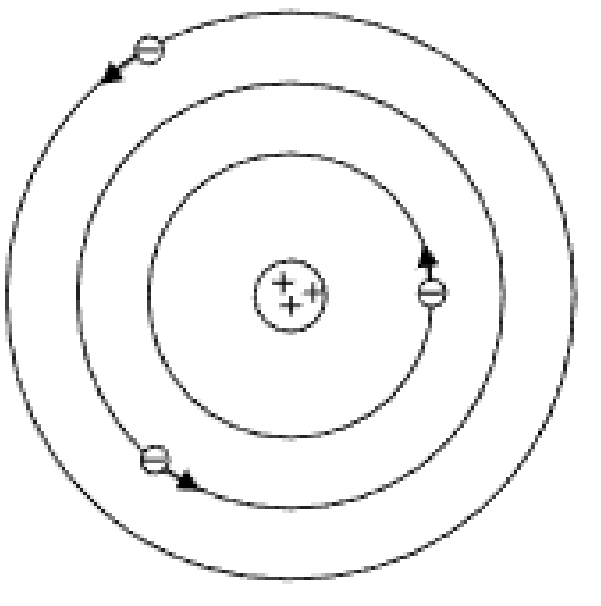
The late nineteenth century (roughly 1880 – 1900) was a time of blissful ignorance for physicists. Many physicists believed that Newton's mechanics and Maxwell's E&M could explain everything. Boy, were they wrong!

Three revolutions in our understanding of the physical world occurred in the 20th century:
1) Special Relativity, a theory of space and time (Einstein 1905)

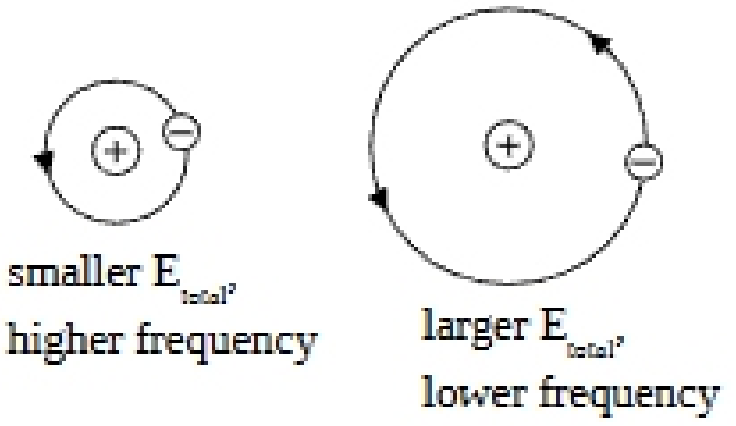
2) General Relativity, a theory of gravity (Einstein, 1916)

3) Quantum Mechanics, a theory of the behavior of atoms (Planck, Einstein, Bohr, Heisenberg, Schrodinger, Born, Dirac, Pauli, …, 1900-1928)

In 1911, Ernest Rutherford (New Zealand/Britain) did an experiment that showed that an atom consists of a small, heavy, positively-charged nucleus, surrounded by small light electrons. The electrons are held in orbit around the positive nucleus by the coulomb force (similar to a planet in orbit around the sun, held by the gravitational force).



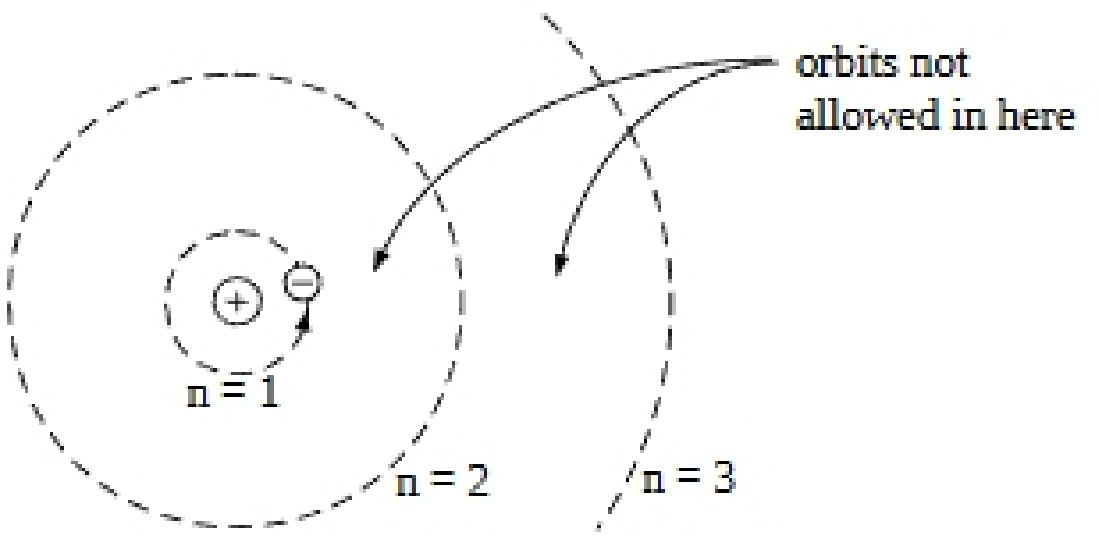
The electron has a total energy E_{tot} = KE+PE. Classical E&M and Newton's mechanics predicts that the electron can have any total energy. One can show that higher energy corresponds to a larger radius orbit with a longer period T (lower frequency f = 1/T).

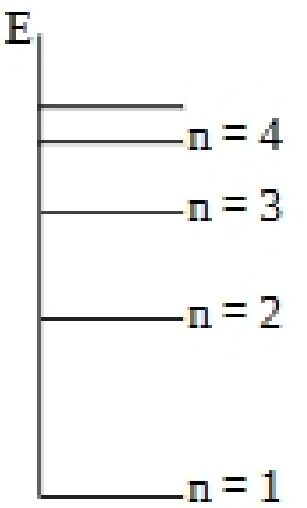


But if the electron can have any total energy, it can orbit with any frequency. And the atom can then give off light of any frequency. (Recall that if a charges shakes with frequency f, it gives off light of that same frequency f.) However, this prediction conflicts with experiment. Experimentally, it is found that atoms only give off light at certain specific frequencies. Each

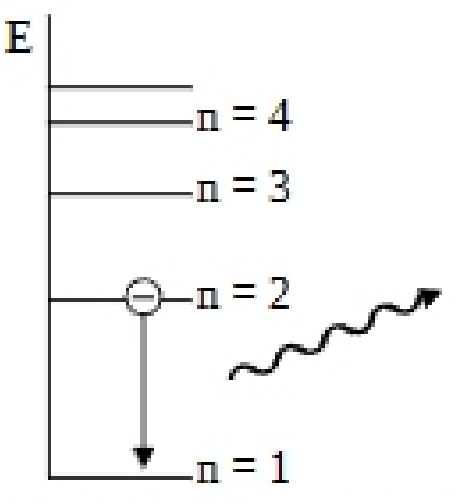
element (H, He, C, N, O, etc) emits a pattern of light at particular frequencies. The pattern of frequencies give a unique fingerprint which can be used to identify the element producing the light.

In the early 20th century (roughly 1918–1928), a new theory called **Quantum Mechanics,** was developed to explain the behavior of atoms. Quantum mechanics predicts that only certain electron energies are allowed in an atom. Classical mechanics predicts that any energy is possible, and so the allowed energies form a *continuum*; quantum mechanics predicts that only certain energies are allowed and so the energies are *quantized*, that is, discrete. The allowed energies are labeled with a *quantum number* n. The quantum number n = 1 is the label for the lowest allowed energy state, called the *ground state*. Higher energy states (n = 2, 3, etc) are *excited states*. The separation between energy levels is usually about a few eV's (1 eV = 1 electron-volt = 1.6 □ 10^{-19} J)

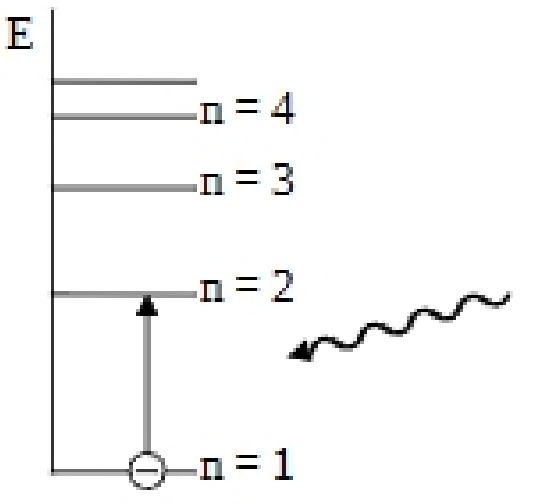




Light is emitted from the atom when the atom makes a transition from a higher-energy state to a lower energy



transition to lower n
light emitted



light absorbed
transition to higher n

state. Light is absorbed by the atom when it makes a transition from a lower-energy state to a higher-energy state.