9.1: Introduction

We begin our discussion of quantum mechanics with something familiar; try filling a cup with water. We know that we cannot put any more than *one* cup of water in there, right? If someone asked "how much water could go in this cup?" your answer might be “any amount of water less than *one* cup will fit in here.”

Water isn't a continuous quantity though, it's composed of individual H_2O molecules. A standard cup is 250 mL, which is roughly 8.4×10^{24} molecules of water (the exact number is not important. You cannot split a water molecule in half (and still call it water) so you cannot fit *any* amount of water into the cup: you must have zero molecules of water, one molecule of water, or 8.4×10^{24} molecules of water in the cup. We say that the amount of water in the cup is *quantized* because the amount water in the cup can only take certain allowed values (multiples of 1 molecule).

In *quantum mechanics*, almost every quantity we encounter (such as energy and angular momentum) can only take certain allowed values. The word “quantum” is derived from the Latin word *quantus*, the same root word as quantity. The name quantum mechanics reminds us that many of the things that we discuss only appear in discrete values. So far, when objects interact by exchanging energy, momentum or angular momentum, we've assumed that we could transfer *any* amount of energy or momentum we wished. However quantum mechanics tells us that we can only transfer these things in discrete pieces (because they are quantized). Here we will focus on quantization of energy and see what the consequences are.

With the example of water, knowledge of molecules makes it easy to visualize why water is quantized. If something is quantized, it's individual pieces are called *quanta* (singular: quantum). The quantum of water is one molecule. Now consider something abstract, like energy. Is the quantum of energy always the same? The answer to this is no: the allowed energies of a system (and therefore the energy quanta), depend on the situation. For example, an atom has different allowed energies than a mass on a spring. One of the mathematically more difficult parts of quantum mechanics is finding the allowed energies of a given system.

We will focus on three specific systems which display rather unique quantization of energy: a particle confined in a one-dimensional box, the hydrogen atom, and a simple harmonic oscillator (a mass on a spring, atomic bonds, etc). We study these three systems to help understand how only being allowed to transfer specific amounts of energy will affect the properties of a system. But first we explore how energy is quantized in the first place, and some of the strange nature of very small objects.