2. Quantum Tunneling

Imagine a ball at the bottom of a hill. If I give the ball an impulse it will begin to roll up the hill. If I pushed hard enough, so that the kinetic energy of the ball is greater than the potential energy needed to get over the edge of the hill, then the entire ball rolls over the hill. If I did not push hard enough, none of the ball can get over the edge and all of it will roll back down the hill. Quantum mechanics shows a much different outcome for this experiment if performed on a much smaller scale (Figure 2). The ball is now an electron and the barrier is a repulsive electric field. If I give the electron enough momentum so that classically it would make it through the field, we see instead that most of the electron goes through as expected, but some actually gets reflected! Even more surprisingly, if I only push the electron weakly so that classically I expect the electron to be reflected completely, I instead see that some of the electron has managed to make it through the barrier. This is called tunneling. Now in reality we do not see half an electron go through a barrier and half get reflected. The electron does not break up. If you perform the experiment and measure which side of the barrier the electron is found, you will find that 50% of the time the electron will be reflected and 50% of the time the electron will be transmitted. So if I send a beam of electrons at the barrier, a current, then it will appear as though half the current passes through the barrier and half is reflected. The fraction that is transmitted is known as $T$, the transmission coefficient, and this quantity is of prime importance in this study.
Tunneling will eventually stop the shrinking of conventional transistors, so is there a device that fundamentally incorporates tunneling into its function that can act as a replacement for the conventional transistor? The basic component of a transistor is a diode, so we need to construct a diode which uses tunneling. This is the concept of the resonant tunneling diode, or RTD. To see how to create one of these devices we need to learn a bit more about the electronic structure of semiconductors.