Electron Tunneling

In the chapter "Electrical Energy and Current," we discussed current as the motion of charge carriers, which we treated as particles. But, as discussed in the "De Broglie Waves" appendix feature, the electron has both particle and wave characteristics. The wave nature of the electron leads to some strange consequences that cannot be explained in terms of classical physics. One example is *tunneling,* a phenomenon whereby electrons can pass into regions that, according to classical physics, they do not have the energy to reach.

Probability waves

To see how tunneling is possible, we must explore matter waves in greater detail. De Broglie's revolutionary idea that particles have a wave nature raised the question of how matter waves behave. In 1926, Erwin Schrödinger proposed a wave equation that described the manner in which de Broglie matter waves change in space and time. Two years later, in an attempt to relate the wave and particle natures of matter, Max Born suggested that the square of the amplitude of a matter wave is proportional to the probability of finding the corresponding particle at that location. This theory is called *quantum mechanics.*

Tunneling

Born's interpretation makes it possible for a particle to be found in a location that is not allowed by classical physics. Consider an electron with a potential energy of zero in the region between 0 and L (region II) of **Figure 1.** We call this region the *potential well.* The electron has a potential energy of some finite value U outside this area (regions I and III). If the energy of the electron is less than U, then according to classical physics, the electron cannot escape the well without first acquiring additional energy.

The probability wave for this electron (in its lowest energy state) is shown in **Figure 2** on the next page. Between any two points of this curve, the area under the corresponding part of the curve is proportional to the probability of finding the electron in that region. The highest point of the curve corresponds to the most probable location of the electron, while the lower points correspond to less probable locations. Note that the curve never actually meets the x-axis. This means that the electron has some finite probability of being anywhere in space. Hence, there is a probability that the electron will actually be found outside the potential well. In other words, according to quantum mechanics, the electron is no longer confined to strict boundaries because of its energy. When the electron is found outside the boundaries established by classical physics, it is said to have *tunneled* to its new location.

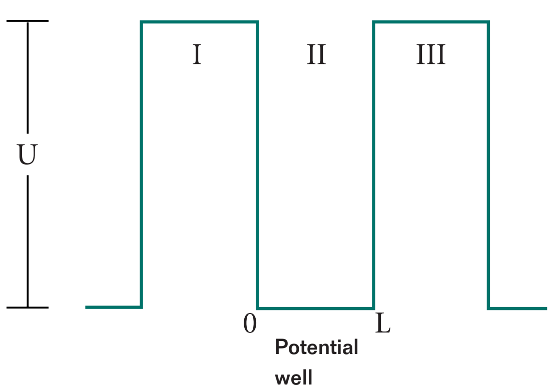

Figure 1
An electron has a potential energy of zero inside the well (region II) and a potential energy of U outside the well. According to classical physics, if the electron's energy is less than U, it cannot escape the well without absorbing energy.