Tunnel Diodes

A variation on the tunneling problem is to consider two such barriers separated by some distance $L$, i.e., a square well with walls of finite height $V_0$ and finite thickness $a$ as illustrated by the potential barriers in Figure 6-32. A particle originally in the well moves back and forth, striking the walls periodically. Each time it strikes a barrier, it has a small but finite probability of tunneling through it and escaping. Such quantum mechanical tunneling is at the heart of a number of physical phenomena or devices such as the tunnel diode and the superconducting Josephson junction.

As we might expect, electrons approaching the twin barriers from outside have a probability, albeit small, of tunneling through both of them, as shown by the wave packet approaching the pair of barriers in Figure 6-32. The region between the barriers is a finite well, with walls of thickness $a$ rather than infinity as in Section 6-3, and solution of the Schrödinger equation leads to quantization of the energy, just as in our earlier discussion. This leads to the very interesting result that, if the velocity $v$ of the electrons approaching from outside the well is such that their kinetic energy $E_k$...
matches the energy of one of the quantized levels in the well $E_n$, then the width of the well is equal to a half-integer number of electron de Broglie wavelengths $\lambda$.

$$L = \frac{n}{2} \frac{\lambda}{\lambda} = \frac{nh}{2p} = \frac{nh}{2\sqrt{2mE_k}} = \frac{nh}{2\sqrt{2mE_n}} = 6-80$$

This means that the multiply reflected waves inside the well interfere constructively and as a result the transmission of electrons through both barriers can be as large as 100 percent, even though the transmission through one barrier may be less than 1 percent! (This is analogous to a similar resonant effect in the Fabry-Perot interferometer.) This resonant transmission at certain energies led to the development of the resonant tunneling diode by Esaki, Chang, and Tsu.\textsuperscript{18} Such devices, with both equal and unequal height barriers have a number of useful properties. For example, the resonant tunneling diodes illustrated in the accompanying photograph have operated as an oscillator at 720 GHz, a record for solid state devices.