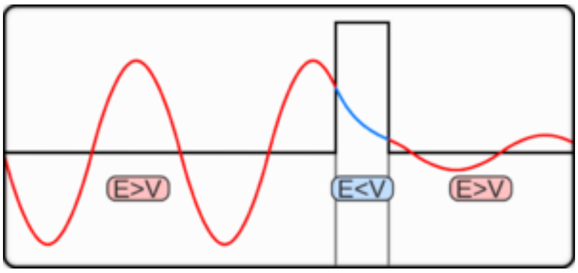

Figure 37: A wave is incident from the left onto a barrier whose repulsive potential, V, exceeds the kinetic energy, E, of the particle. Classically, the particle cannot penetrate the barrier and is reflected (like a ball bouncing off a wall). However the wave is attenuated, but not totally eliminated, so that it has some non-zero amplitude on the right of the barrier, meaning that there is a non-zero probability of finding the particle on the right hand side of the barrier.

9 Quantum Tunnelling

One of the most spectacular phenomena of Quantum Physics is **"quantum tunnelling"**. This is a process in which a particle can cross a barrier, even though the barrier presents a sufficiently large repulsive force, so that classically the particle cannot cross it.

This is demonstrated in Fig. 37, in which a particle of energy E is incident on a barrier from the left which provides a repulsive potential that is larger than E, so that classically the particle is always reflected at the barrier. This happens whenever the height of the potential barrier exceeds the energy of the particle - the particle then does not have enough energy to overcome the force presented by the potential barrier. However, in terms of a wave, the barrier will act to attenuate, but not eliminate, the wave. Mathematically, this follows from the solution to the wave equation in the presence of a potential barrier. Physically, what is happening is that a wave does not suddenly stop when it reaches a boundary between two media but continues with an ever-decreasing amplitude, at least until it reaches another boundary into the original medium. In that case, the wave extends to the right of the barrier but with a reduced amplitude. In terms of the probabilistic interpretation of de Broglie waves, in which the probability of finding the particle is proportional to the square of the amplitude, this means that there is some probability to find the particle to the right of the barrier, although this is considerably less than the probability of find the particle to the left. In this way the particle has some probability to end up on the right of the barrier. The wider the barrier, the lower the probability of finding the particle on the other side of the barrier.

You may have experienced this, in the context of light waves. If you shine a torch into a thick slab of plastic, which is opaque, you cannot see any light getting through. When a medium is said to be "opaque", it does not mean that the wave simply stops when it reaches that medium, but that its amplitude is attenuated becoming negligible after a certain distance into the medium. However, if you shone the light through a very thin piece of the same plastic (e.g. a tiddlywink) you can see some light shining though the thin plastic. As the light penetrates the plastic, its intensity is attenuated so that the thicker the plastic slab the smaller the amplitude of the transmitted light. In terms of a photon, viewed as a particle, the opaqueness of the plastic means that there is a repulsive force acting on the photon which prevents it from penetrating the slab of plastic. The fact that for a thin slab we do see some light, albeit with lower intensity, is a manifestation of the fact that some of the photons are undergoing quantum tunnelling through the plastic.