Eq. de Schrodinger - poço quadrado infinito

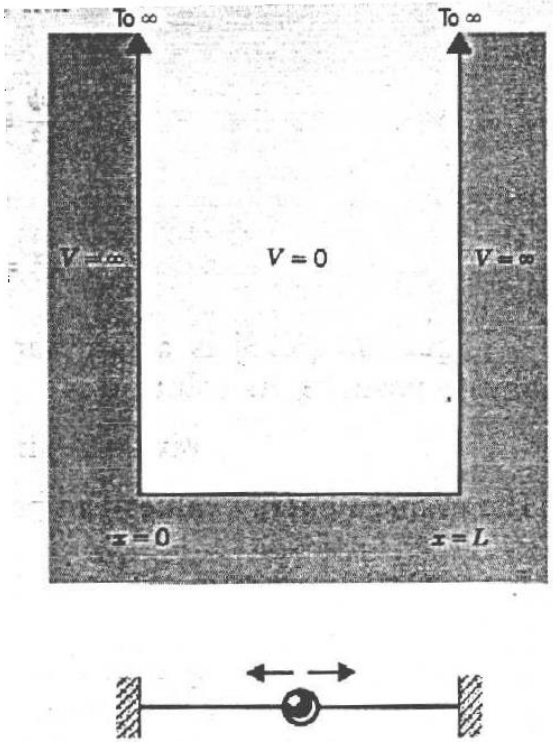

FIGURE 5.3 A particle moves freely in the one-dimensional region $0 \leq x \leq L$, but is excluded completely from $x < 0$ and $x > L$.

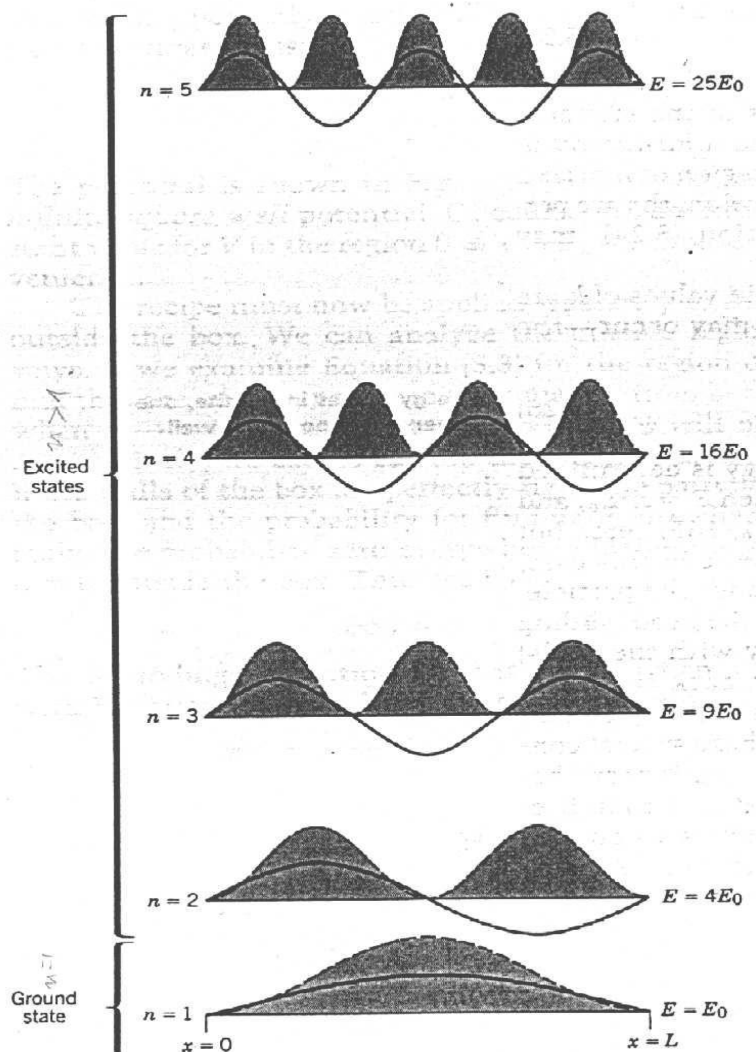

FIGURE 5.4 The permitted energy levels of the one-dimensional infinite square well. The wave function for each level is shown by the solid curve, and the shaded region gives the probability density for each level.

Eq. de Schrodinger - poço quadrado 2D

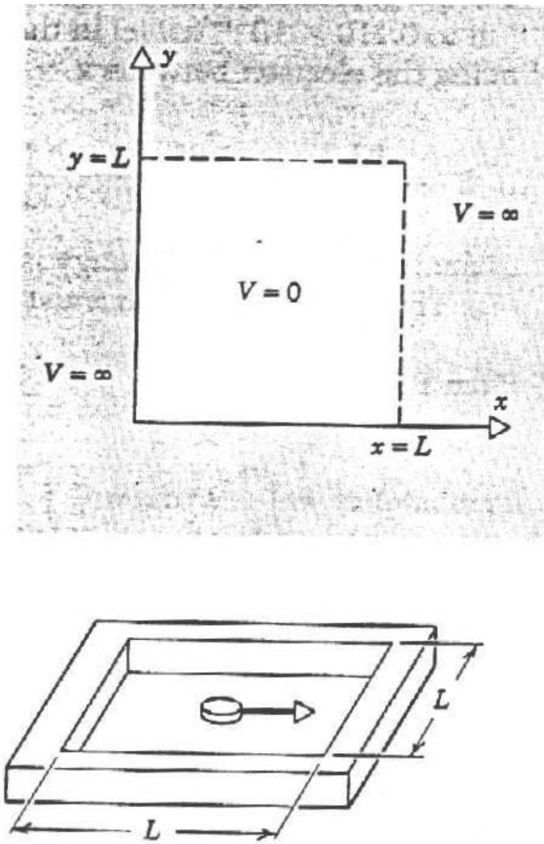

FIGURE 5.5 A particle moves freely in the two-dimensional region $0 \le x \le L$, $0 \le y \le L$.

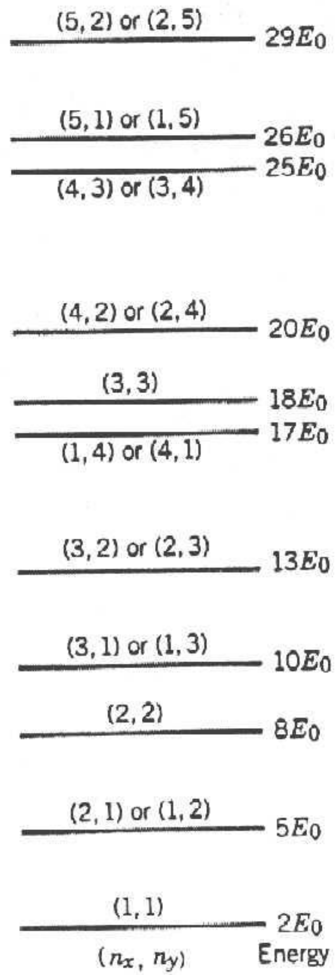

FIGURE 5.6 The lower permitted energy levels of the particle confined to the two-dimensional box.

Estado de mesma Energia

↓

degenerescência

↓

Nível de energia degenerado

Eq. de Schrodinger - poço quadrado 2D

Degenerescência ⇒ Energia igual e distribuição similar
(1,2) e (2,1), (1,3) e (3,1), (3,2) e (2,3), (7,1) e (1,7)

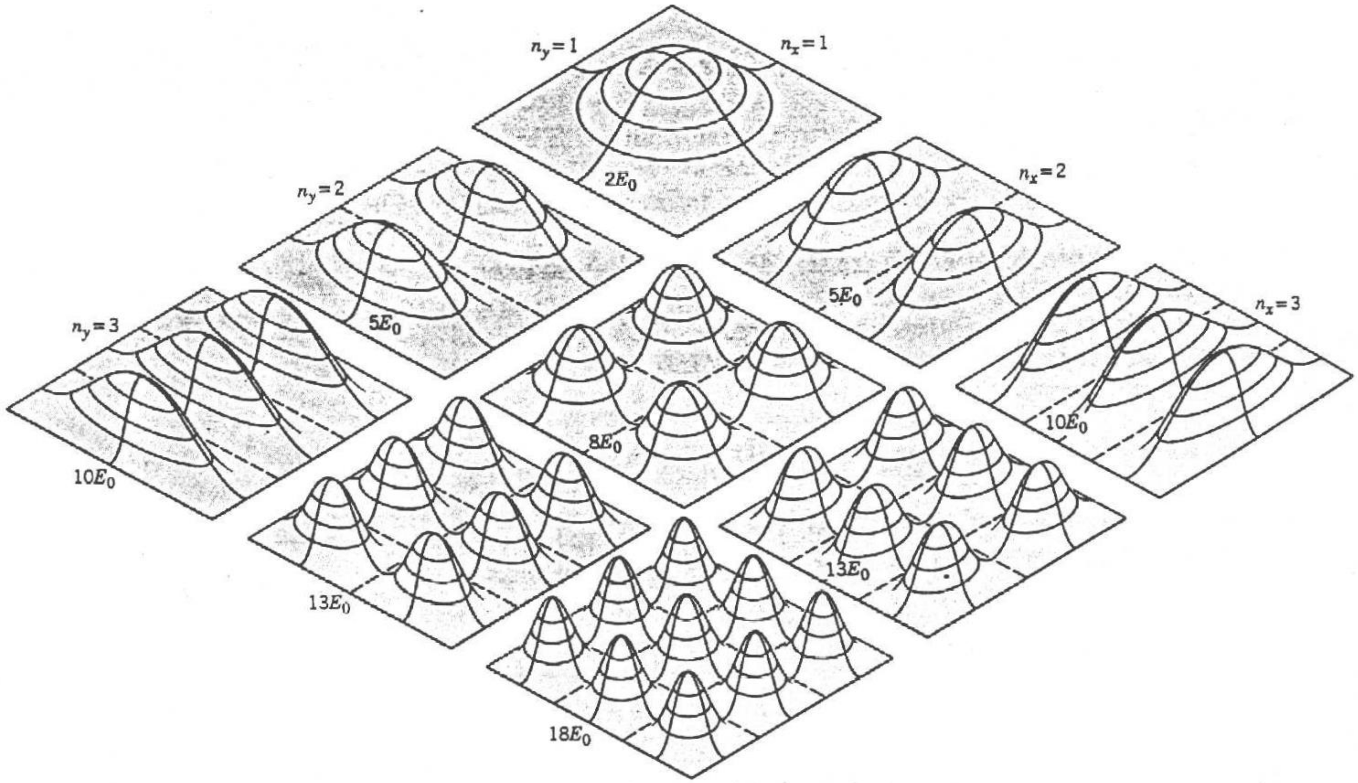

FIGURE 5.7 The probability density ψ^2 for some of the lower energy levels of the particle confined to the two-dimensional box.

Eq. de Schrodinger - poço quadrado 2D

Degenerescência ⇒ Energia igual e distribuição diferente
E=50Eo ⇒(7,1) e (1,7) similar dist. ⇒(5,5) dist. diferente

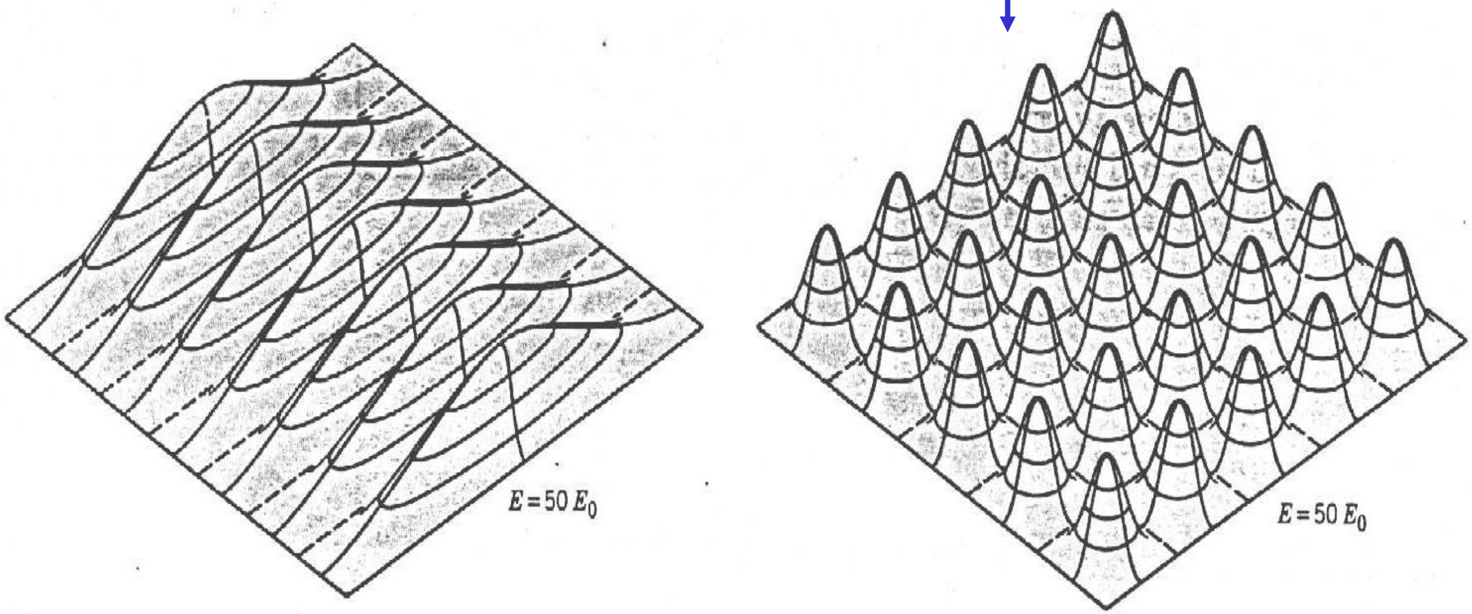

FIGURE 5.8 Two very different probability densities with exactly the same energy.

Eq. de Schrodinger - oscilador harmônico simples

Regiões proibidas classicamente

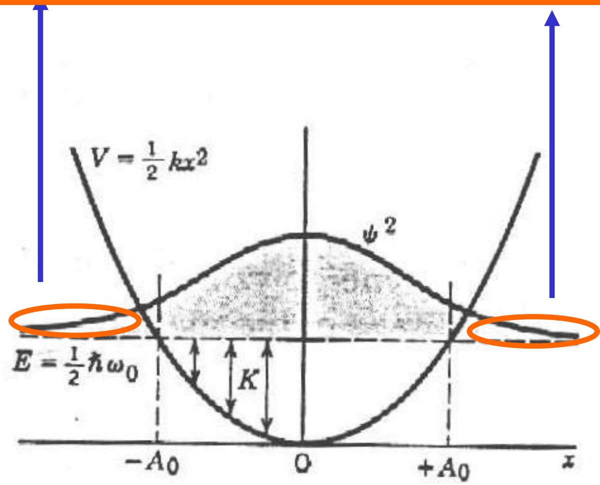

FIGURE 5.9 The ground state of the one-dimensional harmonic oscillator. The kinetic energy K is the difference between the total energy E and the potential energy $V = \frac{1}{2}kx^2$. Classical physics does not permit the particle to move beyond the classical turning points $x = \pm A_0$, where its kinetic energy would be negative. The probability density ψ^2 extends beyond the classical turning points, so there is according to quantum physics some probability for the particle to enter the classically forbidden region.

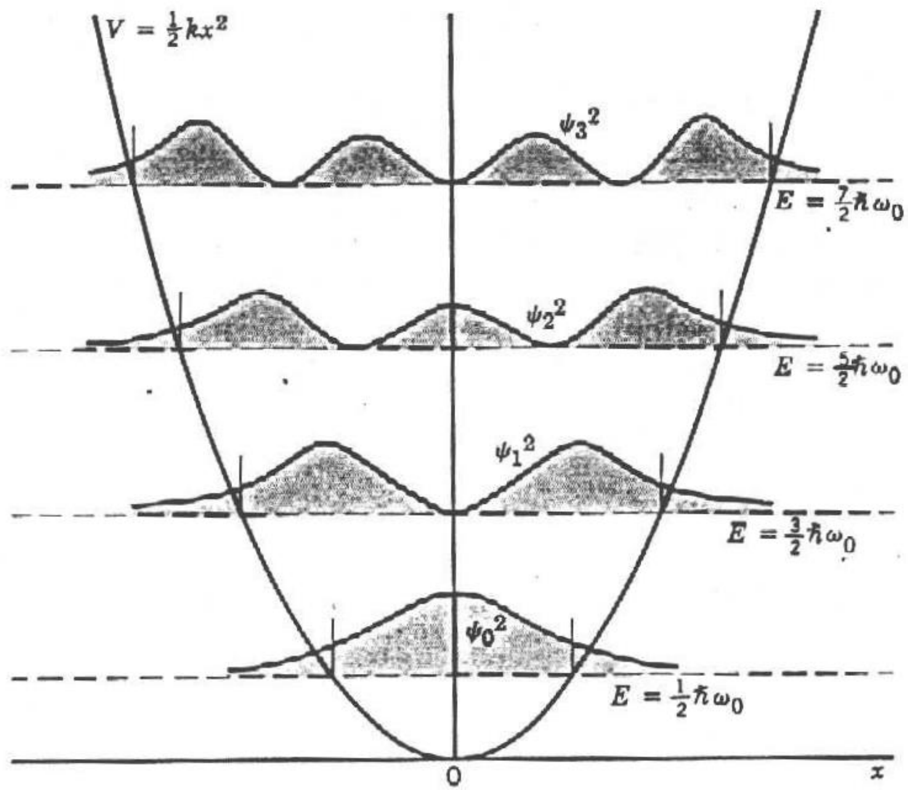

FIGURE 5.10 The lowest few energy levels and corresponding probability densities of the harmonic oscillator.

Eq. de Schrodinger - degrau p/ E>Vo

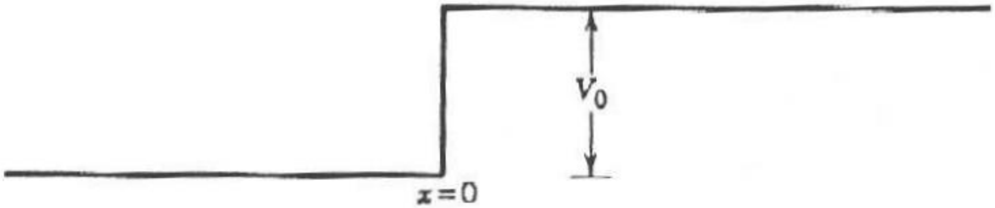

FIGURE 5.11 A step of height V_0.

Ocorreu reflexão da onda incidente

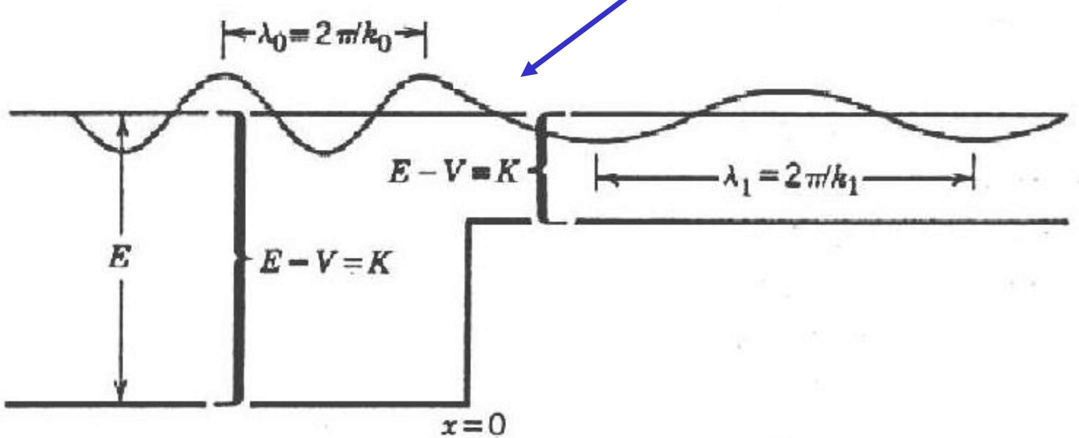

FIGURE 5.12 The wave function of a particle of energy E encountering a step of height V_0, for the case $E > V_0$. The deBroglie wavelength changes from λ_0 to λ_1 when the particle crosses the step, but ψ and $d\psi/dx$ are continuous at $x = 0$.

Eq. de Schrodinger - degrau p/ E<Vo

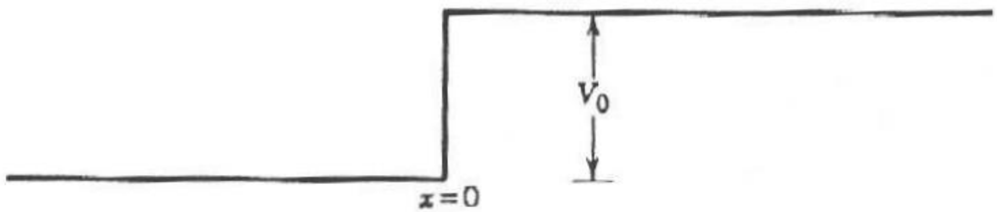

FIGURE 5.11 A step of height V_0.

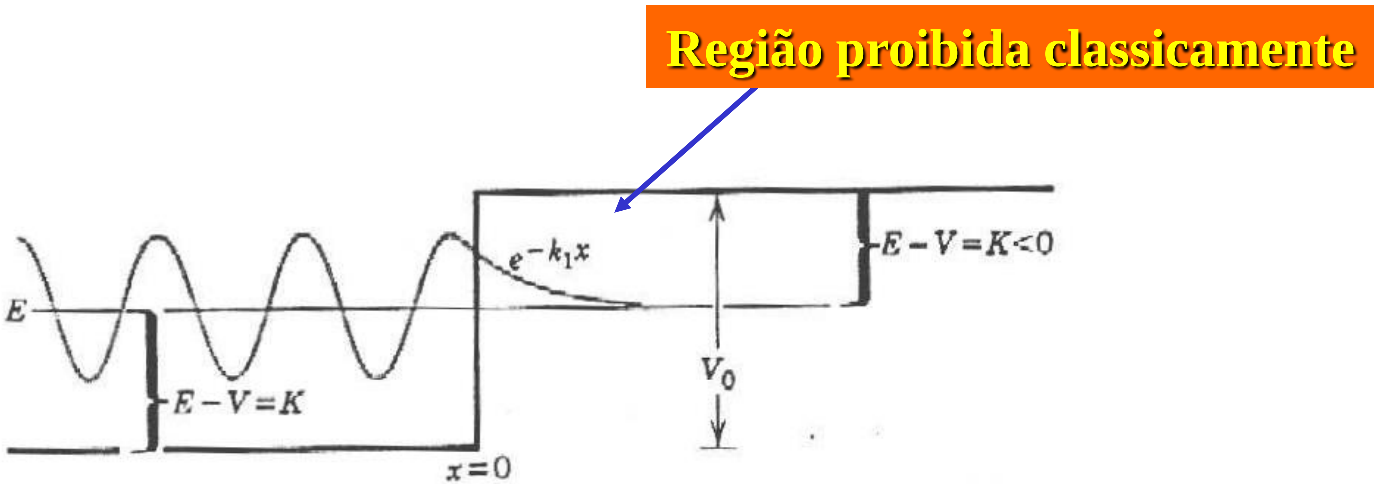

FIGURE 5.13 The wave function of a particle of energy E encountering a step of height V_0, for the case $E < V_0$. The wave function decreases exponentially in the classically forbidden region, where the classical kinetic energy would be negative. At $x = 0$, ψ and $d\psi/dx$ are continuous.

Eq. de Schrodinger - barreira de potencial p/ E<Vo

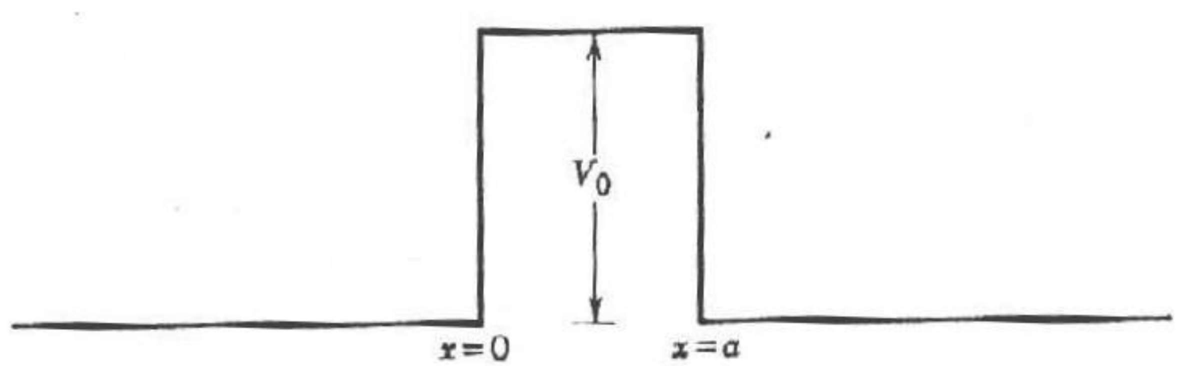

FIGURE 5.14 A barrier of height V_0 and width a.

Região proibida classicamente ⇒ tunelamento quântico

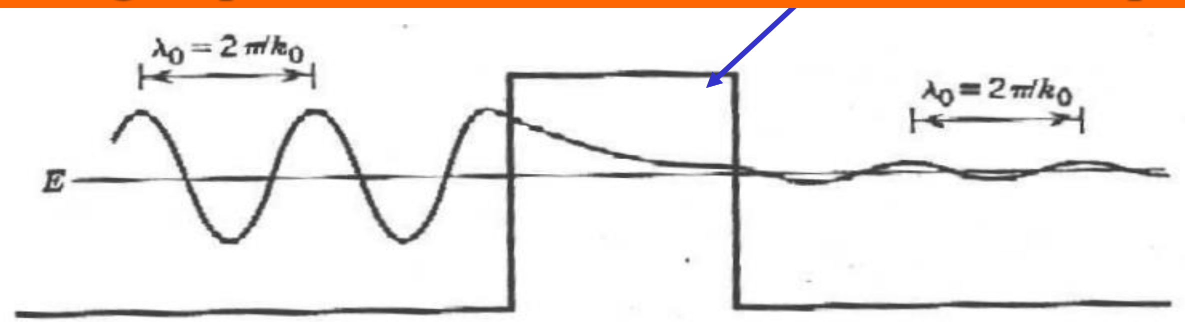

FIGURE 5.15 The wave function of a particle of energy $E < V_0$ encountering a barrier potential (the particle would be incident from the left in the figure). The wavelength λ_0 is the same on both sides of the barrier, but the amplitude beyond the barrier is much less than the original amplitude. The particle can never be observed inside the barrier (where it would have negative kinetic energy) but it can be observed *beyond* the barrier.

Tunelamento

Partícula alfa

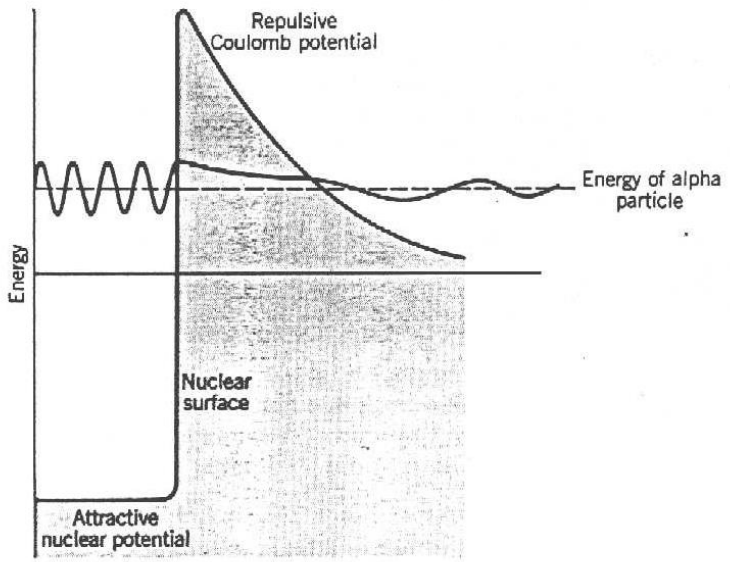

FIGURE 5.16 An alpha particle penetrating the nuclear potential barrier. The probability to penetrate the barrier depends on its thickness and its height.

Inversão da amônia

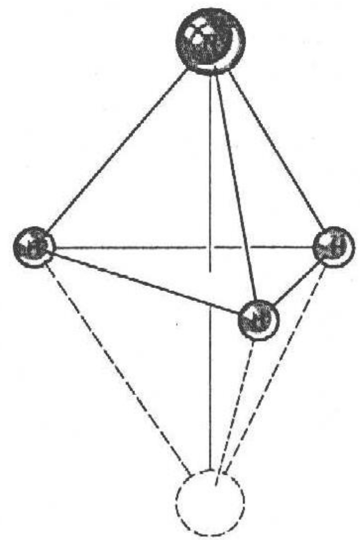

FIGURE 5.17 A schematic diagram of the ammonia molecule. The Coulomb repulsion of the three hydrogens establishes a barrier against the nitrogen atom moving to a symmetric position (shown in dashed lines) on the opposite side of the plane of hydrogens.

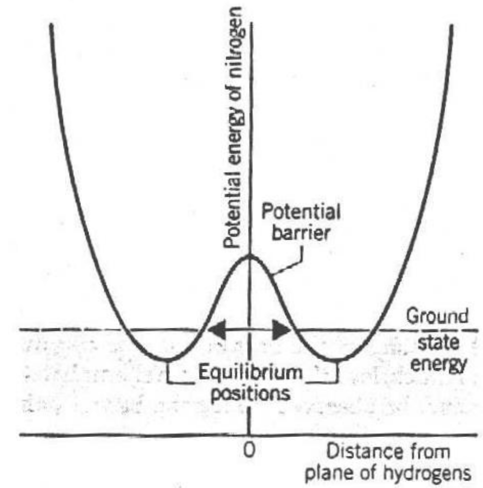

FIGURE 5.18 The potential energy seen by the nitrogen atom in an ammonia molecule. The nitrogen can penetrate the barrier and move from one equilibrium position to another.

Tunelamento

Diodo túnel

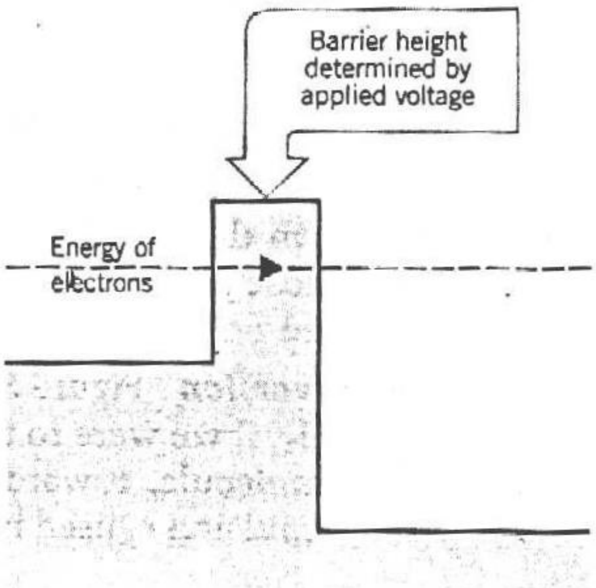

FIGURE 5.19 The potential barrier seen by an electron in a tunnel diode. The conductivity of the device is determined by the electron's probability to penetrate the barrier, which depends on the height of the barrier.

Ondas E.M.

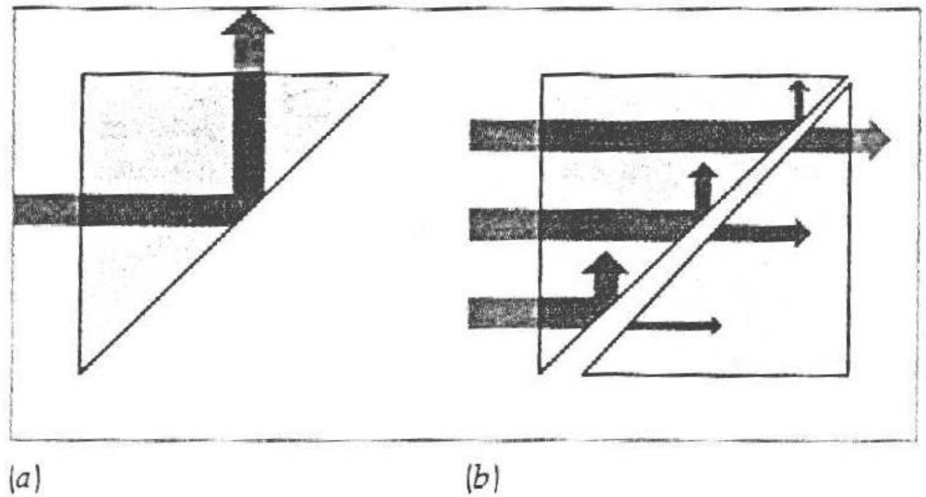

FIGURE 5.20 (*a*) Total internal reflection of light waves at a glass-air boundary. (*b*) Frustrated total internal reflection. The thicker the air gap, the smaller the probability to penetrate. Note that the light beam does not appear *in* the gap.

Tunelamento → Ondas de água

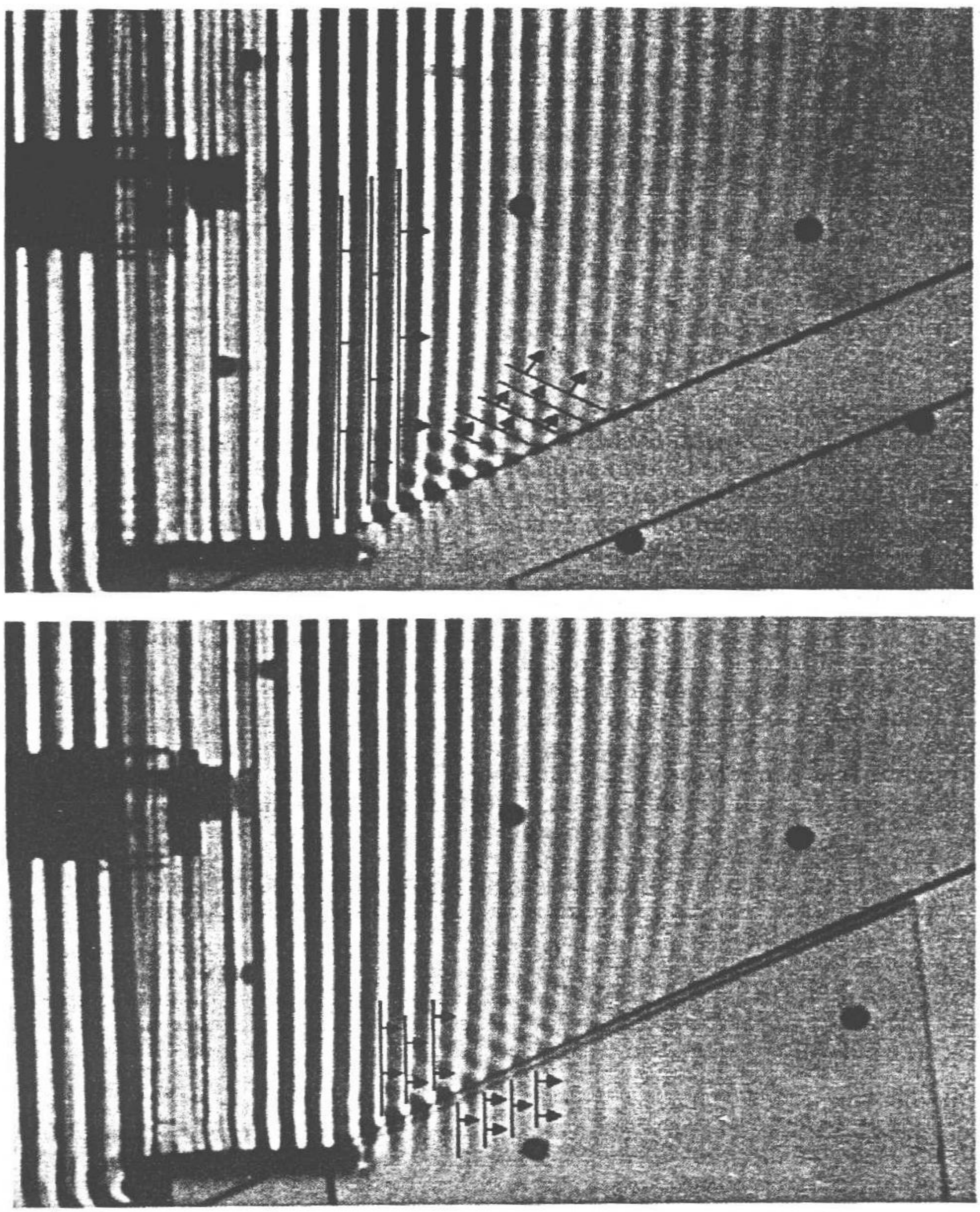

FIGURE 5.21 Frustrated total internal reflection for water waves. At the boundary the depth increases suddenly and the waves are totally reflected. When the gap is made narrow, the waves can penetrate and appear on the other side. (Courtesy of Education Development Center, Inc., Newton, MA.)