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Are particle and photon tunneling and filling in barriers local or non-local phenomena?

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Abstract

It is shown that particle and photon tunneling exhibits a non-local behaviour. This is also true for the wave filling in a semi-closed barrier with a dead stopper. In this connection, we discuss and define for the first time the penetration time of such a barrier in the wave-packet approach. © 2001 Elsevier Science B.V. All rights reserved.

1. It is known (see, for instance, Refs. [1,2]) that, when a non-relativistic-particle wave packet in one dimension

$$\Psi(x,t) = \int dE\, g\big(E - \langle E\rangle\big) e^{ikx - iEt/\hbar} \tag{1}$$

(with $E = \hbar^2 k^2/2m$ being the energy of a monochromatic component, and $g(E - \langle E\rangle)$ the weight amplitude) penetrates inside a 1D potential barrier of rectangular form of width a and height V_0, if $E < V_0$ for any wave-packet component, then *only* evanescent and anti-evanescent waves $\psi_\mp(x,k) = \exp(\mp\kappa x)$ ($\kappa = \sqrt{2m(V_0 - E)}/\hbar$) are present along the x-axis. And what is the physical meaning of wave packets

$$\Psi_\pm(x,t) = \int dE\, g\big(E - \langle E\rangle\big) \psi_\mp(x,k) e^{-iEt/\hbar} \tag{2}$$

inside the barrier?

First of all, (i) one can easily see that the *stationary fluxes* for both $\psi_\pm(x,k)$ are *equal to zero*, and (ii) the *non-stationary fluxes*

$$j_\pm(x,t) = \mathrm{Re}\left(\frac{i\hbar}{2m}\right)\left[\Psi_\pm(x,t)\frac{\partial \Psi_\pm(x,t)^*}{\partial x}\right] \tag{3}$$

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