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Time-dependent scattering by an asymmetric spin-dependent rectangular potential in nanostructures

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The time-dependent aspects of reflection from and transmission through a potential step/barrier/well have recently acquired relevance not only in view of renewed interest in the fundamental problems of measuring time in quantum mechanics but also due to important practical applications in the newly emerged field of nanoscience and nanotechnology. The asymmetric (spin-dependent) rectangular potential barrier/well can model the one-dimensional potential profile in layered magnetic nanostructures (with sharp interfaces) switched from the parallel configuration of magnetic layers (symmetric potential) to the anti-parallel configuration of layers.

An exact solution to the time-dependent Schrödinger equation for the wave function $\psi(r,t)$ of a particle moving in the presence of an asymmetric rectangular well/barrier potential varying in one dimension is obtained. The solution describes the transmission through and reflection from this potential as a function of time. It is presented in terms of integrals of elementary functions and is a sum of the forward- and backward-moving components of the wave packet. The relative contribution of these components and their interference as well as of the potential asymmetry to the probability density $|\psi(x,t)|^2$ and particle dwell time in the different spatial (relatively to the potential location) areas is considered and numerically visualized for narrow and broad energy (momentum) distributions of the initial Gaussian wave packet. It is particularly shown, that in the case of a broad initial wave packet, the quantum mechanical counterintuitive (and classically forbidden) effect of the influence of the backward-moving components on the considered quantities becomes essential. The influence of the potential asymmetry in this case is also more pronounced.

The obtained results may be useful for the kinetic theory of nanostructures.