A DELTA BARRIER IN A WELL AND ITS GENERALIZATION FOR EMISSION STUDIES

K. L. Jensen[1,*], J. M. Riga[2], A. Shabaev[3], M. Osofsky[4], J. C. Prestigiacomo[3], J. J. Petillo[1]

[1] Leidos, Tewksbury, MA USA [2] Air Force Research Laboratory, Albuquerque, NM [3] Naval Research Laboratory, Washington, DC USA [4] Towson University, Towson, MD USA

* Corresponding Author: kljensen@ieee.org[1]

One of the simplest models of tunneling makes use of a δ-function barrier $V(x) = \hbar^2\gamma\delta(x)/2m$ which depends on a single parameter γ, making it a useful tool to examine a variety of technologically important applications (*i*) theoretical predictions of photoemission from materials such as cesiated GaAs surfaces often include a high and thin barrier at the surface attributed to a submonolayer coating of an alkali metal such as cesium to bring theoretically predicted yields in line with photoemission experiments; (*ii*) time evolution simulations of quantum mechanical (QM) tunneling effects using the Wigner distribution function (WDF) and Schrödinger equation (SE) use the δ-function barrier differently to gauge how abruptness and symmetry affect numerical time evolution and because the δ-function barrier demonstrates that the passage of a wave packet incident through it is delayed, even though the barrier is of zero thickness; (*iii*) the δ-function describes IV characteristics of normal-superconducting (NS) point contacts where the transition from the metallic to the superconducting limit is governed by a strength γ of the barrier. Left and right states are coupled, affect the crossover from metallic to small-area tunnel-junction behavior and impact current calculations and charge imbalance processes at the normal-superconducting (NS) interface; and (*iv*) the interest in conduction, transport, and/or emission when either the barriers or wells have a time dependent behavior, for which using steady state emission equations may be insufficient demand the creation of new exact methods that we consider. In such cases, an examination of the physics of tractable models give a means to examine methods useful for more complex configurations.

The analytic model of a δ-function barrier inside a confining well is extended to exactly evaluate the eigenstates and show their dependencies. The time evolution of a superposition of the lowest eigenstates is considered for barriers having comparable Gamow tunneling factors so as to quantify the impact of barrier height and shape on time evolution in a simple and exact system, and thereby serve as a proxy for tunneling time. Lastly, density profiles and associated quantum potentials are examined for coupled wells to show changes induced by weaker and wider barriers. The single parameter δ-function model is useful for the rapid evaluation of current density and is demonstrated. The simplicity of the barrier is further useful in drawing a connection between quantum well bound state problems to tunneling and transport problems, but it is a blunt tool that forces the eigen-energies in a closed system to take on simple limiting values. In the present work, we examine the eigenstates associated with a δ-function barrier in a confining well with infinite walls to identify how the δ-function barrier relates to the more complicated barrier representations. The methods are to be generalized to examine barriers of other shapes that differ from the rectangular barrier by a shape factor to simulate how barrier parameters affect either the dynamic behavior associated with density migration from one side of the well to the other through the barrier or the parameterization of the NS interface.

References

[1] K. L. Jensen *et al.*, "A delta barrier in a well and the exact time evolution of its eigenstates," *J. Appl. Phys.*, vol. 133, no. 17, pp. 174402, 2023

[1]Distribution A: Approved for Public Release