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Establishing the relation between instantons and resonant states

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Schrödinger-type eigenvalue problems are ubiquitous in theoretical physics, with quantum-mechanical applications typically confined to cases for which the eigenfunctions are required to be normalizable on the real axis. However, seeking the spectrum of resonant states for metastable potentials or comprehending $\mathcal{PT}$-symmetric scenarios requires the broader study of eigenvalue problems for which the boundary conditions are provided in specific angular sectors of the complex plane. We generalize the conventional path integral treatment to such nonstandard boundary value problems, allowing the extraction of spectral information using functional methods. We find that the arising functional integrals are naturally defined on a complexified integration contour, encapsulating the demanded sectorial boundary conditions of the associated eigenvalue problem. The attained results are applied to the analysis of resonant ground-state energies, through which we identify the previously elusive one-to-one correspondence between decay rates derived from real-time quantum tunneling dynamics and those obtained via the Euclidean instanton method.

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