

Spectral Boundary Conditions in 2d-CFT: Theory and Applications to Free Boson Models

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We present a comprehensive theoretical framework for spectral boundary conditions (SBC) in two-dimensional conformal field theory, with particular focus on free boson models with boundaries. Using gamma-matrix formalism, we introduce a boundary helicity operator $\beta = \gamma_5 \partial_- \sigma$ and analyze its eigenvalue spectrum to classify boundary conditions. We investigate three distinct linear homogeneous boundary conditions: $(\Pi X)|_{\partial M} = 0$, $\partial \sigma (1 - \Pi) X|_{\partial M} = 0$, and $(\Pi X)|_{\partial M} + \partial \sigma (1 - \Pi) X|_{\partial M} = 0$, where Π represents various projection operators (Π_+ , Π_- , Π_0 , Π_o , Π_e). Through Laurent mode expansions and conformal transformations from the infinite strip to the upper half-plane, we derive explicit boundary conditions for the current modes j_n and $\bar{j}_n$ of the free boson theory. Our analysis reveals how different spectral boundary conditions preserve various aspects of conformal symmetry, with implications for the Virasoro algebra generators L_n and $\bar{L}_n$. We compute the corresponding boundary partition function for one of the BCs. This work provides a systematic approach to understanding boundary effects in CFTs and offers new insights into the relationship between spectral properties and conformal invariance in the presence of boundaries.

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