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Boundary Effects in Quantum Field Theory: Hadamard States with Robin Boundary Conditions

The dynamics of quantum fields are profoundly influenced by the presence of boundaries. We investigate a Klein–Gordon field on half-Minkowski spacetime subject to Robin boundary conditions, which couple the field to its normal derivative at the boundary. By constructing the advanced and retarded fundamental solutions of the Klein–Gordon operator, we analyse how the boundary reshapes causal propagation. In particular, we derive a local Hadamard parametrix that incorporates both the standard singular structure and the additional contributions induced by boundary reflections. This framework allows for the definition of Hadamard states, quantum states with controlled short-distance singularities, ensuring the renormalisability of observables, such as the stress-energy tensor, in this geometric setting. Our results provide a rigorous foundation for quantum field theory in the presence of boundaries, and open new directions for exploring boundary effects in both flat and curved spacetimes.

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