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How to formulate the $\mathbb{Z}_8$ topological invariant of Majorana fermion on the lattice

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Topological invariants and their associated anomalies have played a crucial role in understanding low-energy phenomena in quantum field theories. In lattice gauge theory, the standard $\mathbb{Z}$ -valued Atiyah–Singer index is formulated via the overlap Dirac operator through the Ginsparg–Wilson relation, but extensions to more general topological invariants have remained limited. In this work, we propose a lattice formulation of the Arf–Brown–Kervaire (ABK) invariant, which takes values in $\mathbb{Z}_8$. The ABK invariant arises in Majorana fermion partition functions with reflection symmetry on two-dimensional unoriented manifolds, and its definition involves an infinite sum over Dirac eigenvalues that must be properly regularized. By carefully treating the boundary conditions, with and without a domain-wall mass term, we demonstrate that the ABK invariant can be extracted from Pfaffians of the Wilson Dirac operator. We further provide numerical verification on two-dimensional lattices, showing that the $\mathbb{Z}_8$ -valued results on the torus, Klein bottle, real projective plane, and Möbius strip agree with those in the continuum theory.

Parallel Session (for talks only)

Theoretical developments and applications beyond Standard Model

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