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PT Symmetry -- Physics off the Real Axiss

Abstract

The average quantum physicist on the street believes that to have a real energy spectrum and unitary time evolution, a quantum Hamiltonian must be Dirac Hermitian (invariant under combined matrix transposition and complex conjugation). However, the non-Dirac-Hermitian Hamiltonian $H=p^2+ix^3$ has a positive real discrete spectrum and generates unitary time evolution, and thus defines a consistent physical quantum theory. Evidently, the axiom of Dirac Hermiticity is too restrictive. While $H=p^2+ix^3$ is not Dirac Hermitian, it is

PT symmetric; i.e., invariant under combined parity (space reflection) P and time reversal T. The quantum mechanics defined by a PT-symmetric Hamiltonian is a complex generalization of ordinary quantum mechanics. When quantum mechanics is extended to the complex domain, new theories having remarkable properties emerge. For example, the PT-symmetric Hamiltonian $H=p^2-x^4$, which has an upside-down potential, defines two distinct phases, an unstable phase having complex eigenvalues and a stable phase whose energy levels are all real, positive, and discrete.