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PT-symmetric quantum mechanics: Physics off the real axis

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Abstract: The average physicist would say that to have a real energy spectrum and unitary time evolution a quantum Hamiltonian must be Dirac Hermitian: invariant under complex conjugation+matrix transposition. However, the non-Dirac-Hermitian Hamiltonian $H=p^2+ix^3$ has a positive discrete spectrum and generates unitary time evolution, so H defines a consistent physical quantum theory. Thus, Hermiticity symmetry is too restrictive. While H is not Dirac Hermitian, it is PT symmetric (spacetime-reflection symmetric); that is, invariant under parity P+time reversal T. The quantum mechanics (QM) defined by a PT-symmetric Hamiltonian is a complex generalization of ordinary QM. If QM is extended to the complex domain, new theories having remarkable properties emerge. For example, $H=p^2-x^4$, which has an upside-down potential, defines two distinct phases, an unstable P-symmetric phase having complex eigenvalues and a stable PT-symmetric phase whose energy levels are positive and discrete. The properties of PT-symmetric classical and quantum systems are under intense study by theorists and experimentalists; many theoretical predictions have been verified in laboratory experiments.

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