Special Issue

Quantum and Classical Mpemba Effects: From Theoretical Models to Practical Applications

Message from the Guest Editors

The Mpemba effect, refers to the counterintuitive phenomenon where hot water freezes faster than cold water under certain conditions. First documented by Mpemba and Denis Osborne in 1969, this effect traces back to observations made by Aristotle and has sparked debates for centuries. Explanations for the Mpemba effect vary, including evaporation, convection, supercooling, and dissolved gases. Recent studies suggest it arises from nonequilibrium dynamics, where initial conditions influence relaxation rates. Theoretical frameworks like Markovian dynamics and kinetic theory model this effect, showing that systems can exhibit nonmonotonic relaxation times based on their initial states. Models such as the double-well potential for Brownian particles and mean-field spin systems demonstrate the effect, with some predicting a "strong" version where relaxation is exponentially faster. Quantum analogs have also been explored, linking the effect to entanglement and open-system dynamics. Despite progress, the Mpemba effect remains partially understood, with ongoing research aiming to unify its mechanisms and harness its implications for thermodynamics and material science.

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