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Distinguishability of Particles in Glass-Forming Systems

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The distinguishability of particles has important implications for calculating the partition function in statistical mechanics. While there are standard formulations for systems of identical particles that are either fully distinguishable or fully indistinguishable, many realistic systems do not fall into either of these limiting cases. In particular, the glass transition involves a continuous transition from an ergodic liquid system of indistinguishable particles to a nonergodic glassy system where the particles become distinguishable. While the question of partial distinguishability of microstates has been treated previously in quantum information theory, this issue has not yet been addressed for a system of classical particles. We present a general formalism for quantifying particle distinguishability in classical systems. Example calculations for a simple glass-forming system demonstrate the continuous onset of distinguishability as temperature is lowered. We also examine the loss of distinguishability in the limit of long observation time, coinciding with the restoration of ergodicity. We discuss some of the general implications of our work, including the direct connection to topological constraint theory of glass. We also discuss qualitative features of distinguishability as they relate to the Second and Third Laws of thermodynamics.