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Mechanical Instabilities at Finite Temperature

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The “softness” of soft materials often originates from their proximity to mechanical instabilities. Recent advances in soft matter research have revealed multiple classes of mechanical instabilities, featuring different scalings, different patterns of emergent rigid structure, and even different orders of rigidity transitions. These interesting behaviors have been observed in a wide range of systems, from granular packings to biological tissues and self-assembled structures. In this talk, we review this rich spectrum of behavior and discuss dramatic effects of thermal fluctuations near mechanical instabilities. We discuss a few ordered and disordered lattice models that represent different classes of mechanical instabilities, and show using analytic theories how thermal fluctuations lead to interesting finite-temperature phase diagrams in each case. In particular, (i) using a square lattice model that exhibits a mechanical instability towards exponentially many degenerate ground states, we show that fluctuations can drive the mechanical instability to a first-order transition, owing to divergent fluctuations near the isostatic point; and (ii) using two classes of disordered lattices, we show how under-coordinated random networks can be stabilized by fluctuations and discuss various regimes of unusual entropic rigidity, sharing similarities with jammed packings at finite temperature.