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A Lagrangian variational formulation for nonequilibrium thermodynamics

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Abstract

The principle of critical action, which asserts that the actual trajectories of a conservative system are stationary points of the system’s action functional, tends to be universal in nature. It allows the derivation of the equations of motion and conservation laws in all branches of physics, from discrete and continuum mechanics to general relativity and quantum physics. As such, this variational principle has become an indispensable tool for theoretical, modeling, and computational advances in these areas.

In this talk I will present an extension of this principle to the realm of nonequilibrium thermodynamics in its macroscopic description. The resulting variational formulation is an extension of Hamilton’s principle which incorporates irreversible processes such as friction, heat and matter exchange, and chemical reactions. The structure of the variational formulation is reminiscent of the Lagrange-d’Alembert approach and allows the treatment of both closed and open thermodynamic systems. Several examples will be treated, such as interconnected systems and reacting fluid flows. Comments will be given towards applications to modelling and numerical discretization.

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Keywords: Lagrangian, variational principle, nonequilibrium thermodynamics, Hamilton’s principle