# MECHANICAL ENGINEERING PhD SEMINAR

**Thursday, January 1, 2026, at 13:30, Lady Davis Building, Auditorium 250**

## Training Dynamical Responses in Mechanical Systems

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Processing information is essential to both living and engineered systems. In living systems, this emerges from physical processes such as chemical reactions and electrical signals. Engineered systems, on the other hand, typically rely on central processors to analyze signals and extract meaningful information, often through the implementation of AI and machine learning algorithms. Harnessing physical processes could allow computation in hardware, which might be more efficient, cheaper, and integrated. While there have been large advances in the 'quasistatic' regime, the dynamic regime, in which responses cannot be described by instantaneous equilibrium relations, has been largely unexplored.

The aim of the current research is to explore how physical systems such as mechanical structures or simple electronic networks can perform a given desired dynamical function. Moreover, this research aims to develop a framework for training such systems in hardware, without the use of an external CPU. This line of research could open the door to intelligent materials that process dynamical signals, enabling temporal computations, frequency-dependent filtering, and passive sensing for classification.

We begin by optimizing dynamical steady states in disordered spring networks, governed by damped Newtonian dynamics. Using backpropagation through time and gradient descent, we design spatially specific steady states with prescribed amplitudes, frequencies, and phases. By varying damping, we interpolate between the underdamped and overdamped regimes, mapping the feasibility and constraints of complex and exotic dynamical functions. Convergence is shaped by chaos, long relaxation times, attenuation, and finite-time gradient biases, while eigenmode analysis shows how networks reorganize to perform task-specific responses within physical bounds.

Building on these insights, we extend equilibrium propagation to damped mechanical systems and RLC circuits. Equilibrium propagation is a framework that computes exact gradients using the system's own physical response, enabling autonomous learning with only local information. By defining an effective action whose extremum corresponds to the underlying dynamics, we derive local learning rules applicable to both periodic and resting initial conditions. We demonstrate this autonomous learning framework in simulation and explore novel temporal functionalities, including frequency-dependent filtering, sound classification, and passive or active sensing.

Note: the seminar will be given in English

Seminars Coordinator: Prof. Sefi Givli