



MECHANICAL ENGINEERING MSc SEMINAR (30 min.)

Thursday, October 8 2026 at 13:30-14:00, Lady Davis Building, Auditorium 250

Periodic response of the Duffing resonator

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Many microelectromechanical systems (MEMS), such as micro-gyroscopes, energy harvesters, and advanced sensors, are constructed from vibrating mechanical resonators. While these systems are often modeled as linear, this assumption breaks down at high vibration amplitudes. As displacement amplitude increases, the mechanical restoring force becomes highly nonlinear. The simplest model of a nonlinear resonator is the Duffing resonator, which includes linear and cubic stiffness terms. There is no explicit analytic solution for the damped and driven Duffing resonator. To predict the response of the system, engineers historically relied on various perturbation and approximation techniques, such as the harmonic balance method (HBM) and the method of averaging. While these approximation methods accurately capture the response of the system at small displacement, they often obscure physical intuition as they rely heavily on mathematical techniques. To provide a more physically grounded solution for the response of the Duffing resonator, we propose a new approximation approach. The new energy balance method (EBM) relies solely on work-energy considerations, balancing change in the mechanical energy of the system with the net-work done by the non-conservative forces, in any time interval during the fully developed periodic response. While the EBM effectively captures the behavior of the system under moderate driving amplitudes, the dynamic landscape changes at larger actuation amplitudes. As massive energy is supplied to the system, highly complex nonlinear behaviors are unveiled. The final section of this seminar explores two such nonlinear phenomena: symmetry-breaking bifurcations, where the symmetric oscillation loses stability and abruptly shifts off-center, and isolated resonances (isolas), which are hidden, subharmonic orbits completely detached from the primary frequency response curve.