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**Nanoscale Mechanical Resonators for Probing Physical Phenomena: Fluid Dynamics of High-frequency Flows**[1]

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With their miniscule sizes, high frequencies, and small force constants, nanoelectromechanical systems (NEMS) resonators are expected to emerge as tools for sensing a variety of analytes, for probing biological entities, and for measuring molecular-scale forces. Because many of these foreseeable applications are in fluids, it is natural to consider the operation of NEMS resonators in fluids. When immersed in a fluid, however, the NEMS resonator loses most of its vibrational energy to the fluid. In other words, the quality factor (Q) of the resonator decreases significantly. Reductions in Q result in a reduction in the resonator's sensitivity to added mass or force. In order to understand the fluid dynamics of NEMS, we have revisited a well-known fluid dynamics problem: Stokes' second problem of the oscillating plate in a fluid. At the typical frequencies of NEMS resonators, Stokes' second problem needs to be reformulated using a relaxation time approach in order to accurately describe the fluidic effects. Our experiments and theory show that the fluid relaxation time in conjunction with the resonator frequency determines the nature of the flow; linear dimension and geometry appear to have weak effects. Our results support a universality in oscillating flows and suggest a deep connection between simple and complex fluids. With this understanding, we are making progress toward reducing NEMS dissipation in water.

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