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Effects of Length Scale and Frequency in Oscillatory Flows Induced by Micro- and Nano-mechanical Resonators KAMIL EKINCI, VURAL KARA, VICTOR YAKHOT, Department of Mechanical Engineering, Boston University — It is challenging to formulate a theory of flows induced by oscillating micro- and nano-mechanical resonators even in simple fluids. The characteristic length and time scales of these devices may lead to surprising deviations from classical fluid dynamics. Here, we study this problem in a near-ideal gas. By changing the gas pressure, we control the mean free path and the relaxation time of the gas. We measure, as a function of pressure, the fluidic dissipation of micro- and nano-mechanical resonators with length scales (sizes) and frequencies that span many orders of magnitude. We show conclusively how a subtle interplay between its length scale (size) and frequency determines the nature of flow around a mechanical resonator, resulting in a low-frequency regime dominated by length scale and a high-frequency regime dominated by frequency. We propose an analytical formula that incorporates both the dimensionless size and frequency and show excellent agreement over the entire parameter space between theory and experiment. Our results are significant for understanding high-frequency and nanoscale fluid-structure interactions as well as for designing improved devices.

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