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Critical mass and vortex dynamics for rising and falling spheres
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We study the dynamics of spheres rising or falling freely through a fluid at two different Reynolds numbers, Re = 450 and 10,000. At both values of Re, falling spheres, which have a mass ratio, or relative density greater than 1, descend rectilinearly. In the case of a rising sphere, we find that there exists a critical value of the mass ratio, below which the sphere will undergo large-amplitude oscillations. Despite the difference in the modes of vortex formation at these two Reynolds numbers (due to the instability of the separated shear layer at higher Re), a critical mass exists for both cases. For the higher Reynolds number, we find a critical mass ratio of 0.61, in good agreement with the result for tethered and elastically mounted spheres at similar Re (Govardhan and Williamson, 2004, JFM). At Re = 450, performing experiments in glycerin-water mixtures to allow for precise control of the Reynolds number, we find that the critical mass ratio takes a distinctly lower value of 0.36. Using laser-induced fluorescence to visualize the wake of a vibrating sphere at this Reynolds number reveals another interesting phenomenon; rather than two alternately signed vortex loops being shed in a cycle, as might be expected, four vortex structures are shed in each cycle of oscillation.

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