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Vanishing limit of a ball in a rotating fluid-filled rigid body

We consider the physical system consisting of a hollow rigid body $\mathcal{B}$ whose cavity contains a homogeneous rigid ball B_R of radius R. Let the gap between $\mathcal{B}$ and B_R be entirely filled by a viscous incompressible fluid, and assume that the center of mass G of the whole system remains fixed during the motion. We are interested in the *vanishing limit* of the inner core B_R to a massless point as $R \to 0$, along solutions to the equations governing the *free rotations* of the whole system around G.

The equations of motion are given by the Navier–Stokes equations for the fluid and the balances of angular momentum for the two solids. We show that *weak solutions* to these equations converge (in an appropriate topology) to weak solutions of the equations governing the inertial motions of a fluid-filled rigid body (i.e., of the fluid-solid system without the inner core B_R). In addition, the long-time dynamics of the latter system can be recovered through the limit $R \to 0$ from the long-time dynamics of the system with the inner core B_R. These results show that the dynamics of a fluid-filled rigid body is robust under the singular perturbation obtained by inserting a small rigid core into the fluid-filled cavity.