

ADDED MASS, DENSITY STRATIFICATION AND BUOYANCY OSCILLATIONS

Bruno Voisin ^{*1}

¹LEGI, Université Grenoble Alpes, CNRS, Grenoble INP, 38000 Grenoble, France

*contact: bruno.voisin@cnrs.fr

Added mass represents the additional inertia experienced by a body as it moves through a fluid, owing to the flow that this motion generates within the fluid. When waves are present, added mass becomes complex at any given frequency, with a real part associated with inertia and an imaginary part with wave damping. We consider the way internal waves affect the added mass of oscillating bodies in uniformly stratified fluids. As for potential flow, the energy and impulse of the fluid, the dipole strength of the body and the forces exerted on it may all be expressed in terms of added mass, which then provides direct access to the wave energy, of primary importance for internal tides (Garrett and Kunze, 2007), and to the forces governing the dynamics of oceanographic floats (Goodman and Levine, 1990; D'Asaro, 2018). By Fourier inversion in time, added mass appears as a new memory force acting in addition to the Basset force associated with viscous effects.

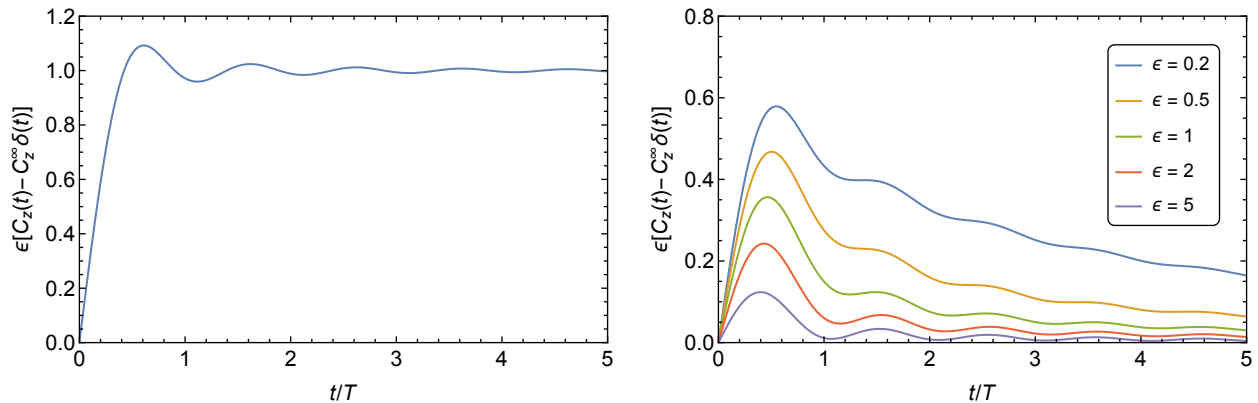


Figure 1: Memory kernel for the vertical motion of a horizontal elliptic cylinder (left) and a spheroid of vertical axis (right). Both bodies have horizontal semi-axis a , vertical semi-axis b and aspect ratio $\epsilon = b/a$. Time t is expressed in terms of the buoyancy period T , and the added mass coefficient is C_z^∞ without stratification and C_z with it.

Added mass is calculated for the translational motion of an elliptic cylinder and a spheroid, based on their earlier study using boundary integrals (Voisin, 2021). Particular attention is paid to the oscillations of a sphere displaced from its neutral buoyancy level then released (Larsen, 1969; Levitskii and Chashechkin, 1999), to the oscillations of a Cartesian diver (Le Gal *et al.*, 2022), and to the measurement of added mass by the impulse response method (Brouzet *et al.*, 2017).

References

- Brouzet C., Ermanyuk E. V., Moulin M., Pillet G., Dauxois T. (2017). Added mass: a complex facet of tidal conversion at finite depth. *Journal of Fluid Mechanics* 831, 101–127.
- D'Asaro E. (2018). Oceanographic floats: principles of operation. In R. Venkatesan, A. Tandon, E. D'Asaro, and M. A. Atmanand (Eds.), *Observing the Oceans in Real Time*, pp. 77–98. Springer.
- Garrett C., Kunze E. (2007). Internal tide generation in the deep ocean. *Annual Review of Fluid Mechanics* 39, 57–87.
- Goodman L., Levine E. R. (1990). Vertical motion of neutrally buoyant floats. *Journal of Atmospheric and Oceanic Technology* 7(1), 38–49.
- Larsen L. H. (1969). Oscillations of a neutrally buoyant sphere in a stratified fluid. *Deep-Sea Research* 16(6), 587–603.
- Le Gal P., Castillo Morales B., Hernandez-Zapata S., Ruiz Chavarria G. (2022). Swimming of a ludion in a stratified sea. *Journal of Fluid Mechanics* 931, A14.
- Levitskii V. V., Chashechkin Y. D. (1999). Natural oscillations of a neutrally buoyant body in a continuously stratified fluid. *Fluid Dynamics* 34(5), 641–651.
- Voisin B. (2021). Boundary integrals for oscillating bodies in stratified fluids. *Journal of Fluid Mechanics* 927, A3.