

Monochromatic internal waves from oscillating objects

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Realization that mixing in the ocean owes much to the generation of internal tides by the ebb and flow of the surface tide over continental slopes¹, on one hand, and advent of the synthetic schlieren method for the measurement of internal waves in the laboratory², on the other hand, have led to a regain of interest in the generation of monochromatic internal gravity waves. This problem is tackled here in two parts.

First, the structure of the waves from an arbitrary monochromatic source term is investigated. Waves are radiated along beams, of inclination to the vertical determined by the frequency, while the structure of the waves inside the beams is determined by additional phenomena such as the size of the forcing and the viscosity of the fluid³. Transitions take place, between regions where each phenomenon dominates in turn (figure 1a). Near-field effects are prominent in three dimensions, and are proposed as an explanation for the discrepancy between experiment and existing, far-field, theories⁴.

Secondly, the determination of the source terms equivalent to oscillating circular cylinders and spheres is considered. The variations of their added mass with frequency is predicted, and is shown to coincide with experiment⁵. Taking these into account, the radiated energy is shown to exhibit a maximum at a practically constant fraction of the buoyancy frequency, independent from the direction of oscillation (figure 1b). Implications for stratified turbulence are discussed.

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¹St. Laurent and Garrett, *J. Phys. Oceanogr.* **32**, 2882 (2002).

²Dalziel et al., *Exp. Fluids* **28**, 322 (2000).

³Voisin, *J. Fluid Mech.* **496**, 243 (2003).

⁴Sutherland et al., *J. Fluid Mech.* **390**, 93 (1999); Flynn et al., *J. Fluid Mech.* **494**, 65 (2003).

⁵Ermanyuk and Gavrilov, *J. Fluid Mech.* **451**, 421 (2002), **494**, 33 (2003).

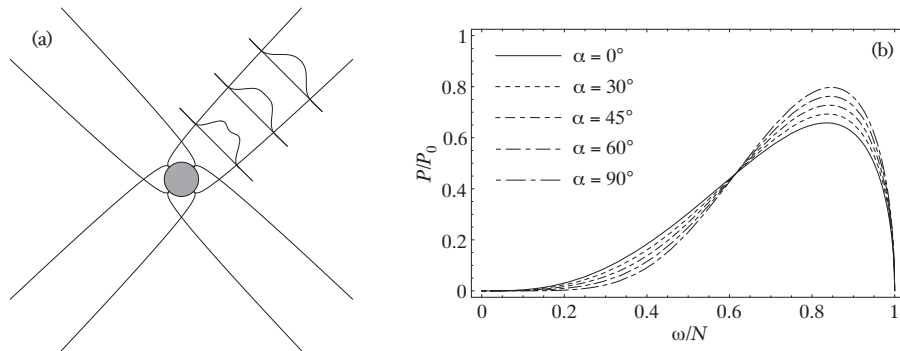


Figure 1: (a) Internal waves from a sphere, exhibiting the transition from a bimodal régime dominated by the influence of its size to a unimodal régime dominated by viscosity, as illustrated by the profile of wave intensity. (b) Radiated power from a sphere versus frequency ω , for different angles of oscillation α to the vertical, exhibiting a maximum at a practically constant fraction, between 0.83 and 0.85, of the buoyancy frequency N .