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Unifying Gravity- and Kinematics-induced Segregation Forces in Dense Granular Flows[1] LU JING, JULIO M. OTTINO, RICHARD M. LUEPTOW[2], PAUL B. UMBANHOWAR, Northwestern University — Particle size segregation is common in many natural and industrial processes involving flowing granular materials. Complex, and even contradictory, segregation phenomena have been observed depending on boundary conditions and forcing. For example, larger particles rise against gravity and toward low shear regions in free surface flows down inclines, but migrate laterally to high shear regions in a silo. Despite recent progress in modeling granular segregation, a universal description remains elusive. We develop a unified scaling for the segregation force on intruder particles consisting of two parts: a gravity-induced pressure gradient term (buoyancy-like but modified by the particle size ratio) and a shear rate gradient term that pushes larger (smaller) intruders toward regions of higher (lower) shear rate. The scaling is obtained by measuring segregation forces on intruder particles in velocity-controlled flows, and then validated (without refitting) in other flow geometries, including wall-driven flows, inclined wall-driven flows, vertical silo flows, and free surface flows down inclines. Comparing the segregation force to the intruder weight predicts the segregation direction in various flow configurations.

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