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Multiphase Flows: Rich Physics, Challenging Theory, and Big Simulations

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Understanding multiphase flows is vital to solving the most pressing human problems: clean air, clean water and the sustainable production of food and energy. Here we will focus on a subset of multiphase flows involving non-deforming particles in a carrier fluid: particle suspensions over a wide range of particle-to-fluid density ratios, ranging from solid particles in a gas (high density ratio) to buoyant particles that approximate small bubbles in a contaminated liquid (low density ratio). We will see that hydrodynamics and heat transfer in these flows result in rich multiscale physics, such as clustering and pseudo-turbulence, with important practical implications. As we attempt to explain and predict these phenomena we will encounter the peculiar challenges that multiphase flows pose for standard statistical mechanics. The need to build accurate closure models for unclosed terms that arise in statistical theories motivates the development of particle-resolved direct numerical simulations (PR-DNS). PR-DNS can be used to discover new multiphase flow physics and develop models. Selected results will highlight recent progress and the talk will conclude with an outline of challenges that lie ahead.