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Flow And Heat Transfer Characteristics of Nanoconfined Fluids

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Abstract

Nanoconfined flow dynamics and heat transfer are governed by strong interfacial interactions and confinement effects, leading to significant deviations from classical continuum theories. This talk summarizes our studies of gas, liquid, and gas–liquid two-phase flows under nanometer confinement. For gas flow, we reveal molecular-size-induced entrance resistance, adsorption-driven surface diffusion, and the scale dependence of the tangential momentum accommodation coefficient, and establish models applicable from angstrom-scale to nanoscale channels. For liquid flow, we clarify the coupled roles of viscosity enhancement, disjoining pressure, velocity slip, and entrance effects, and develop a wall-friction-based model for monolayer water flow. For gas–liquid flow, we identify capillary condensation and evaporation mechanisms and construct a coupled framework of phase equilibrium, interfacial mass transfer, and fluid flow to describe nonlinear transport and flow-regime transitions. For heat transfer, we investigate interfacial temperature discontinuities and develop a generalized two-dimensional Graetz model incorporating nanoscale transport effects. We further clarify the influence of two-dimensional heat fluxes on temperature jumps and propose heterogeneous surface and external electric fields for heat transfer regulation. These studies connect molecular-scale mechanisms with continuum-level modelling and provide a theoretical basis for controlling coupled flow and heat transfer in nanoconfined systems.