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Lattice Boltzmann modeling of microchannel flow in slip flow regime[1]

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We present the lattice Boltzmann equation (LBE) with multiple relaxation times (MRT) to simulate pressure-driven gaseous flow in a long microchannel. We obtain analytic solutions of the MRT-LBE with various boundary conditions for the incompressible Poiseuille flow with its walls aligned with a lattice axis. The analytical solutions are used to realize the Dirichlet boundary conditions in the LBE. We use the first-order slip boundary conditions at the walls and consistent pressure boundary conditions at both ends of the long microchannel. We validate the LBE results using the compressible Navier-Stokes (NS) equations with a first-order slip velocity, the information-preservation direct simulation Monte Carlo (IP-DSMC) and DSMC methods. As expected, the LBE results agree very well with IP-DSMC and DSMC results in the slip velocity regime, but deviate significantly from IP-DSMC and DSMC results in the transition-flow regime in part due to the inadequacy of the slip velocity model, while still agreeing very well with the slip NS results. Possible extensions of the LBE for transition flows are discussed. This work has been published in Journal of Computational Physics.

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