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Verification and Validation of Kinetic Codes

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We review the last three workshops held on Validation and Verification of Kinetic Codes. The goal of the workshops was to highlight the need to develop benchmark test problems beyond traditional test problems such as Landau damping and the two-stream instability. These test problems provide a limited understanding how a code might perform and mask key issues in more complicated situations. Developing these test problems highlights the strengths and weaknesses of both mesh- and particle-based codes. One outcome is that designing test problems that clearly deliver a path forward for developing improved methods is complicated by the need to create a completely self-consistent model. For example, two test cases proposed by the authors as simple test cases turn out to be ill defined. The first case is the modeling of sheath formation in a 1D 1V collisionless plasma. We found that losses to the wall lead to discontinuous distribution functions, a challenge for high order mesh-based solvers. The semi-infinite case was problematic because the far field boundary condition poses difficulty in computing on a finite domain. Our second case was flow of a collisionless electron beam in a pipe. Here, numerical diffusion is a key problem we are testing; however, two-stream instability at the beam edges introduces other issues in terms of finding convergent solutions. For mesh-based codes, before particle trapping takes place, mesh-based methods find themselves outside of the asymptotic regime. Another conclusion we draw from this exercise is that including collisional models in benchmark test problems for mesh-based plasma simulation tools is an important step in providing robust test problems for mesh-based kinetic solvers.

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