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Charged Particle Stopping Power in Dense Plasmas: Improvements, Validation, and Practical Implications[1]

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Charged particle stopping power is an important quantity that arises in thermonuclear burn, particle beam experiments, and fast ignition. Because stopping power models arise from kinetic theory collision operators and stopping power is a velocity-resolved non-equilibrium statistical mechanics problem, exact values of stopping power are ideal quantities for validating collision models. By directly comparing classical molecular dynamics simulations with stopping models derived from both linear response and binary cross section pictures, we have quantified the accuracy of these models and determined which physics is needed as a function of Coulomb coupling, projectile charge, and velocity. We have found that for divergent linear response theories, a velocity-dependent cutoff works better than a simpler temperature-dependent cutoff, but both fail when the velocity of the projectile is low and the Coulomb coupling is large. This problem is somewhat rectified by the inclusion of local field corrections. Alternatively, one can use a binary cross section in constructing a collision operator for better inclusion of strong scattering. We find that low-velocity stopping can be significantly improved by including non-linear screening of the target particles when calculating this cross section. We extend this knowledge to the quantum case, giving the relative contributions of Heisenberg uncertainty, degeneracy, and quantum scattering.

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