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Langmuir's paradox, wave-particle scattering, and the presheath[1]
SCOTT BAALRUD, JAMES CALLEN, CHRIS HEGNA, University of Wisconsin-Madison — Langmuir's paradox, perhaps the oldest unsolved mystery of gas discharge physics, is a measurement of anomalous electron scattering near plasma boundaries. In particular, a Maxwellian was reportedly measured much closer to the boundary than the mean free path for electron scattering in a stable plasma; here one should expect truncation of the distribution function corresponding to the sheath potential energy. In this paper we theoretically analyze the presheath region that is present in Langmuir paradox-relevant plasmas ($T_e \gg T_i$). It is shown that the ion-acoustic instability is present throughout the presheath causing amplification of the thermal fluctuations. A collision operator for the plasma kinetic equation including instabilities in a finite space-time domain is derived which shows that the electron collision frequency is dominated by wave-particle interactions in the presheath by up to 3 orders of magnitude. The collision operator satisfies the Boltzmann $\mathcal{H}$-theorem, so the only equilibrium is a Maxwellian which is achieved at a rate depending on collisionality. Wave-particle scattering shrinks the electron mean free path to within $\sim$cm for these discharges showing that one should expect a Maxwellian at the location of the previously reported measurements.

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