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Plasma-Sheath Model

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In typical gas discharges a quasineutral plasma is shielded from a negativ absorbing wall by a thin positive sheath that is nearly planar and collision-free. The subdivision of "plasma" and "sheath" was introduced by Langmuir and is based on a small ratio of the electron Debye lenghth λ_D to the dominant competing characteristic plasma length ℓ. Depending on the special conditions, ℓ may represent, e.g., the plasma extension, the ionization length, the ion mean free path, the ion gyro radius, or a geometric length. Strictly speaking, this subdivion is possible only in the asymptotic limit $\lambda_D/\ell \to 0$. The asymptotic analysis results in singularities at the "sheath edge" closely related to the "Bohm criterion." Due to these singularities a direct smooth matching of the separate plasma and sheath soltions is not possible. To obtain a consistent smooth transition, the singular sheath edge must be bridged by an additinal narrow "intermediate" model zone accounting both for plasma processes (e.g., collisions) and for the first build up of space charge. Due to this complexity and to different interpretations of the "classical" papers by Langmuir and Bohm, the asymptotic plasma-sheath concept and the definition of the sheath edge were questioned and resulted in controversies during the last two decades. We discuss attempts to re-define the sheath edge, to account for finite values of λ_D/ℓ in the Bohm criterion, and demonstrate the consistent matching of plasma and sheath. The investigations of the plasma-sheath transition discussed so far are based on a simplified fluid analysis that cannot account for the essential inhomogeneity of the boundary layer and for the dominant role of slow ions in space charge formation. Therefore we give special emphasis to the kinetic theory of the plasma-sheath transition. Unfortunately this approach results in an additional mathematical difficulty caused by ions with zero velocity. We discuss attempts to avoid this singularity by a modification of the kinetic Bohm criterion and investigate the influence of slow ions on the structure of the plasma-sheath transition. The most important conclusions are illustrated with selected examples.