

How is the Bohm criterion satisfied in the presence of several positive ions?

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Under most conditions, ions entering the sheath at the edge of a plasma satisfy the Bohm criterion. The place where the Bohm criterion is satisfied may be understood as the boundary between the quasineutral plasma and the spacecharge sheath. When there are several ions present, the Bohm criterion fails to uniquely determine the speeds with which the ions enter the sheath. Instead it prescribes a locus of possible solutions, and in general, we do not know which solution will be realized in any particular case. In a generalization of the Tonks-Langmuir model, and in other cases where essentially all ions have the same mean free path, it has been shown that the realized solution is that each ion leaves the plasma with its own Bohm speed, which is to say, with the same kinetic energy. This seems intuitively reasonable, because in such cases one may assert that all the ions reaching the sheath edge have traversed the same potential drop.

In this paper, we consider a model in which the ion elastic collision frequency is large compared with the ionization frequency. With this assumption, there is a region adjacent to the sheath where the ion fluxes approaching the sheath may be assumed to be constant, and in this region an analytical solution to the transport equations can be found in which the ion motion is mobility limited. For two ion species, this analytical solution is characterized by two dimensionless physical parameters, which are essentially the ratio of the ion fluxes and the ratio of the mean free paths. In this model, the sheath solution must match this bulk transport solution, and this requirement uniquely determines the manner in which the Bohm criterion is satisfied. In fact, one can realize any and every solution of the Bohm criterion by an appropriate choice of the dimensionless parameters.

However, the range of solutions that can actually be realised is severely restricted, essentially by ion-neutral collision physics. We will show that in practice, this means that in most cases the assumption that each ion species enters the sheath at own Bohm speed is a reasonable one.