

## The plasma-sheath transition: its history and different definitions of the sheath edge.

J.E.Allen

University College, Oxford OX1 4BH, United Kingdom.

john.allen@eng.ox.ac.uk

The literature on the plasma-sheath transition is largely based on the pioneering work of Langmuir and of Bohm. Some confusion exists in the published literature, however, resulting in part from an incomplete study of the works of these authors.

Let us first consider the work of Langmuir. In an early paper (1923) Langmuir refers to a region "where there are positive ions but no electrons, and in this region there will therefore be a positive space charge. The outer edge of this *sheath* of ions....". This citation has been quoted, at greater length, in a recent review article by Franklin (2003). In another paper Langmuir and Mott-Smith (1924) considered the sheath around a probe to extend out to a field-free plasma region. A figure in that paper illustrates a charged particle moving in a straight line until it reaches the sheath.

It is clear that one cannot just quote Langmuir (at random) to support one's claim. Not surprisingly Langmuir's ideas developed as his work progressed from 1923 - 1929. It would appear that the famous paper by Tonks and Langmuir (1929) should be taken to be represent Langmuir's view of the matter. According to that paper, the plasma region ends when the Laplacian term in Poisson's equation becomes "equal to a certain fractional part" of either of the other two terms. In physical terms, the sheath begins where quasi-neutrality breaks down.

Let us now turn to Bohm. It is a fact that Bohm's text is not in agreement with his mathematics. But what is generally known as the Bohm sheath criterion is based on his algebra, and not on his "wordy" description. It should also be recalled that Bohm obtained a criterion that contained an inequality sign. The much-used version with the equality sign can only be obtained by considering the plasma region rather than the sheath. The Bohm velocity is attained at the sheath edge, to a high degree of approximation, when  $(\lambda_D/L)$  approaches zero, where L is the appropriate characteristic distance for the problem. Otherwise the Bohm velocity becomes largely irrelevant.

Readers of recent numbers of "Physics of Plasmas" and the "IEEE Transactions on Plasma Science" will have come across different opinions on what is meant by the "sheath edge". Further enlightenment can be found in the review articles by Riemann (1991, 2000).

### References (in chronological order)

Langmuir, I., 1923, Gen. Elect. Rev., 26, 731.

Langmuir, I. and Mott-Smith, H., 1924, Gen. Elect. Rev., 27, 449.

Bohm, D., 1949, The Characteristics of Electrical Discharges in Magnetic Fields, ed.A.

Guthrie and R.K.Wakerling (New York: McGraw-Hill).

Tonks, L. and Langmuir, I., 1929, Phys.Rev. 34, 876.

Riemann, K.-U., 1991, J.Phys.D: Appl. Phys., 24, 493.

Riemann, K.-U., 2000, J.Tech.Phys., 41, 1.

Franklin, R.N., 2003, J.Phys.D: Appl.Phys., 36, R309.