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Probe Theory - the Orbital Motion Approach

additional notes

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Update on "Probe Theory – The Orbital Motion Approach" by J.E.Allen

[1] Allen,J.E., Annaratone,B.M. and de Angelis,U., On the orbital motion limited theory for a small body at floating potential in a Maxwellian Plasma, 2000, J.Plasma Physics,63,299.

Abstract. The condition for the validity of the orbital motion limited theory (OML) is reviewed, with reference to the calculation of the floating potential attained by a spherical body immersed in a plasma. It is shown that the OML theory is never satisfied in Maxwellian Plasmas, even in the case of very small bodies, i.e. those with radii much smaller than the plasma Debye length. The case considered is that where the ion temperature is less than or equal to the electron temperature. The results are relevant to the theory of dusty plasmas, where the OML theory has been much employed.

[2] Kennedy, R.V. and Allen,J.E., The floating potential of spherical probes and dust grains, I: Radial motion theory, 2002, J.Plasma Phys. 67, 243.

Abstract. A theoretical analysis of spherical probes in plasmas is presented. It is assumed that the probe is at floating potential, that ion motion is radial and that the electrons are Maxwellian. The analysis shows that as the probe radius divided by Debye length tends to zero, the ratio of floating potential to electron temperature also goes to zero.

[3] Kennedy, R.V. and Allen,J.E., The floating potential of spherical probes and dust grains, II:Orbital Motion Theory, 2003, J.Plasma Phys. 69, 485.

Abstract. Probe theory is generally used to find the potential of dust particles immersed in plasma. The orbital motion limited theory (OML) is often used to find the potential at the probe surface, but the assumptions underlying this theory are usually not valid in the case of dust and the more general orbital motion theory (OM) is much harder to calculate. Solutions are given for the OM theory in a range of cases applicable to dust. It is shown that the surface potential the full theory gives reduces to the OML result for small probes. Commonly in dusty plasmas the OML surface potential is used, with the surrounding potential given by Debye-Hückel, or Yukawa theory. This form, however, neglects ion depletion due to the absorption of particles on the probe surface. In this paper a new analytical solution is given which is applicable to small particles and dust. This new expression is equivalent to Yukawa form, but takes ion absorption into account.

[4] Annaratone, B.M., Allen, M.W. and Allen J.E., Ion currents to cylindrical Langmuir probes in r.f. plasmas, 1992, J. Phys. D: Appl. Phys., 25, 417-424, 1851.

Abstract. The positive ion current collected by cylindrical Langmuir probes has been measured in an RF argon plasma. The current-voltage characteristics were measured using an RF compensation technique whereby the probe was forced to follow the RF fluctuation in the local plasma potential. The I–V curves from probes of different radii and material show an ion current which is always greater than that predicted by the orbital motion theory and that agrees well with the radial motion theory. This is because the ions travel from a distance which is limited by the vessel geometry or by the collisional mean free path. The role of the possible collisions, ion-ion and ion-neutral, in the ion trajectories is analysed. It is suggested that the criterion for the application of the orbital motion theory should be tested whenever this theory is used.

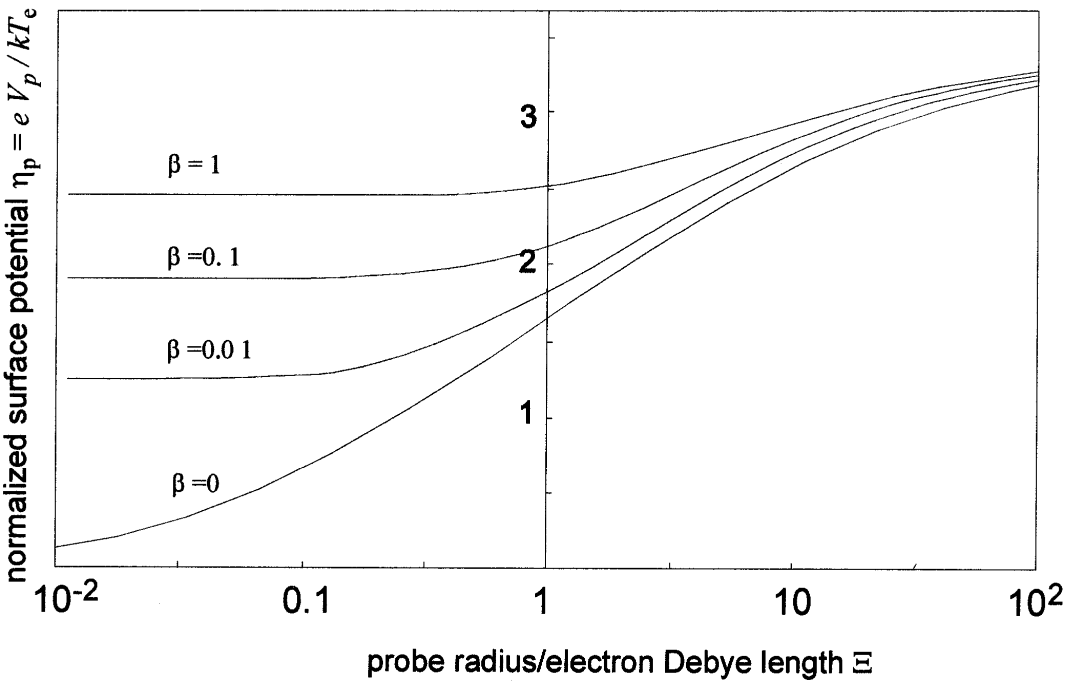

Figure 6. Floating potential as a function of probe radius, for various ratios of ion to electron temperature. Potential is normalized with respect to electron temperature, radius with respect to electron Debye length [4,5,6,7]. The curves are for different values of β, the ratio of ion temperature to electron temperature. The curve $\beta = 0$ corresponds to radial motion of the positive ions.