Thermodynamic approach to dust particles charge in plasmas

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It is rather difficult to work out a unified theoretical approach to determining the charge of dust particles immersed in a plasma. This is explained from the standpoint that the charge of dust particles is governed by the state of ambient buffer plasma, whose parameters can span over a fairly wide range of their variation. For example, in the case of a sufficiently rarefied plasma, the orbital motion limited approximation is known to work well, whereas for a dense plasma one is obliged to apply macroscopic transport equations.

This report deals with an alternative approach based on the chemical model of dusty plasma [1] consisting of electrons, ions and dust particles. In particular, an expression for the free energy of the system is theoretically derived [2] and is then minimized as a function of the plasma constituents number densities, which makes it possible to evaluate the charge of dust particles under the quasi-neutrality condition.

The whole consideration starts from establishing the internal partition function of a dust particle that has absorbed a certain number of electrons. An insight is exploited that a single dust particle is a potential well for electrons, whose depth is determined by the work function of dust material, and after being charged the dust particle creates a macroscopic electric field that possesses a certain positive energy. Such an interpretation allows us to predict the existence of a maximum charge the dust particles can acquire in real experiments and which is determined by the work function of dust material and the dust grain size.

Numerical calculations of the charge of dust particles are performed in quite a broad domain of the plasma density and temperature, and a straightforward comparison is made with the orbital motion limited approximation. It is demonstrated that the proposed calculation scheme predicts larger charge values of dust grains as compared to the orbital motion limited approximation.

REFERENCES

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