ALLOWANCE FOR THE EFFECT OF WEAK COLLISIONS ON STATIONARY POTENTIAL DISTRIBUTIONS

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As established in [1], in stationary electron-ion fluxes emitted by a plane, the reflection of slow particles by the emitter occurs only in the first two potential oscillations, if collisions are not taken into account and the emitter is the only particle source in the space. The present note shows that, when collisions are taken into account, conditions under which slow-particle reflection occurs in the third, fourth, etc., potential oscillation are possible.

In the presence of weak collisions, the filling of potential wells of stationary distribution by particles captured from a flux that goes to infinity is possible when there are particles with a sufficiently low total longitudinal energy ε in the flux. At the same time, it is known [1] that potential wells that are filled by slow particles are deeper than wells without slow particles. Thus, an oscillating potential distribution with increasing amplitude becomes possible when there are more captured particles in each successive hole than in the preceding one.

Let us make two assumptions in order to determine the conditions under which such a distribution could be realized. Let the particles of the flux have a Maxwell distribution with respect to transverse velocities with temperature T (which is the same for electrons and ions), and let the longitudinal energy of the majority of the particles be much greater than the transverse energy. Then the stationary-distribution wells that have depth on the order of the longitudinal energy of the fast particles will be sufficiently deep, i.e., in the first place, they will contain sufficiently many trapped particles and, in the second place, the interaction of the trapped particles with the flux particles will be fairly weak as compared with their interaction with one another. Under conditions of a sufficiently long existence of the stationary distribution, therefore, the trapped particles will have an isotropic Boltzmann distribution with temperature T.

Fig. 1

The amplitude of the distribution function f_1 of trapped particles is determined from the condition of equality of the flux of particles that have entered a well by weak collisions to the flux of particles that have been ejected from the well [2, 3]. In particular, if the boundary values f_+ and f_- (for $v > 0$ and $v < 0$) of the distribution function of untrapped particles f at the critical value of the longitudinal energy ε_*, which separates the trapped particles from the untrapped, coincide, then the boundary value $f_{1\pm}$ for the velocity-symmetric function f_1 will also agree with these values. But if $f_+ \neq f_-$, then the boundary value $f_{1\pm}$ is established somewhere between the boundary values f_+ and f_-.[1] In the case of an oscillating potential distribution with an increasing amplitude, the low-energy part of the flux of untrapped (in a given hole) particles is reflected by the emitter by subsequent potential oscillations, and therefore

$$f_{1\pm} = f_+ = f_- = f(\varepsilon_*). \tag{1}$$

Since collisions are assumed to be fairly rare, it can be assumed, as in [1], that the distribution functions of untrapped particles will satisfy the collisionless kinetic equations of Vlasov. The opposite-sign potential distributions $\varphi(x)$ are determined, as in [1], by the function (Figs. 1 and 2)

$$Y(\varphi \mid x) \equiv \frac{1}{8\pi}\left(\frac{d\varphi}{dx}\right)^2.$$

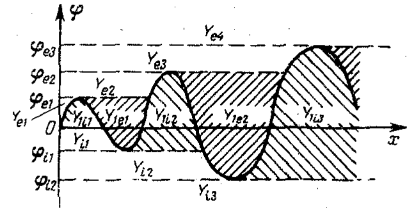

Fig. 2

Here x is the distance to the emitting plane. The inscriptions in Fig. 2 indicate the energy ranges for various groups of reflected and trapped particles, from which we can judge which groups of particles contribute to the function $Y(\varphi \mid x)$ at the given values of φ, x (Y_{ek} is the contribution of electrons reflected from the k-th potential maximum, and Y_{1ek} is the contribution of electrons trapped in a well that is situated after the k-th potential maximum; the symbols are similar for ions). As can be seen from Fig. 1, for an increase in the amplitude of potential oscillations it is sufficient to satisfy the conditions

$$Y_{1ek}(\varphi_{ik}) + Y_{ek+1}(\varphi_{ik}) < Y_{1ek+1}(\varphi_{ik}), \tag{2}$$

$$Y_{1ik}(\varphi_{ek}) + Y_{ik}(\varphi_{ek}) < Y_{1ik+1}(\varphi_{ek}). \tag{3}$$

From condition (1) and the expression of functions Y in terms of the particle-distribution functions [1], it follows that (2) and (3) are satisfied when the distribution functions of the emitted particles with respect to the initial velocity v_0 at the emitter $f_{0i}(v_0)$, $f_{0e}(v_0)$ decrease with an increase in v_0 more slowly than the Maxwell functions $C_e \exp(-mv_0^2/2T)$.

Here C_e and C_i are constants, which are selected such that the Maxwell functions coincide with $f_{0e}(v_0)$, $f_{0i}(v_0)$ for values of v_0 that correspond to the first potential extremes; and m and M are the electron and ion masses. If at high values of v_0 ($v_0 > v_1$) the function f_{0e} (or f_{0i}) begins to decrease more rapidly than the corresponding Maxwell function, then the increase in the amplitude of the potential oscillations will cease when the potential reaches the value $mv_1^2/2e$ (or $Mv_1^2/2e$), where e is the electron charge.

REFERENCES

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