On the hydrodynamics of a two-liquid plasma taking into account relaxation processes

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In his known investigation of a quasi-equilibrium plasma [1] Landau assumed that the distribution function (DF) of the plasma components $f_a(p,t)$ $(a = e, i)$ is the Maxwell one with the time-dependent temperatures and velocities. In the literature on plasma hydrodynamics the same DF is considered as zero-order in gradients contribution to nonequilibrium DF (local equilibrium assumption).

The main idea of the present work is: DF of components of quasi-equilibrium homogeneous plasma should be calculated. It is realized here in a perturbation theory in deviations of the velocities and temperatures of the plasma components from their equilibrium values (the corresponding small parameter μ). The consideration is based on the Landau kinetic equation [1] and a generalization of the Chapman-Enskog method based on the Bogolyubov functional hypothesis $f_a(p,t) \xrightarrow[t \gg \tau_0]{} f_a(p,\tau(t),u(t))$. Here τ, u_n are the deviations of the electron subsystem temperature and velocity from their equilibrium values $(\tau, u_n \sim \mu)$. Expansion of the DF $f_a(p,\tau,u)$ in μ has the form $f_a(p,\tau,u) = w_a(p) + w_a(p)\{A_a(p)\tau + B_a(p)p_n u_n\} + O(\mu^2)$ where $w_a(p)$ are the Maxwell DF with the equilibrium temperature T and velocity. The developed theory allows investigation of nonlinear in μ processes too.

Functions $A_a(p), B_a(p)$ have been calculated by expansion in the Sonine polynomial series. An additional simplification was made by expansion in small parameter $\sigma = \sqrt{m_e/m_i}$. Our consideration shows that *the local equilibrium assumption is valid only approximately*. In the one-polynomial approximation the reverse temperature relaxation time is given by the formula $\lambda_T = \lambda_T^L + O(\sigma^4)$ where $\lambda_T^L = c z^2(z+1)\sigma^2 2^{7/2}/3$ is the Landau expression [1]. In the two-polynomial approximation this quantity has the form $\lambda_T = \lambda_T^L + c z(z-1)\sigma^3 2^3 5^2/3 + O(\sigma^4)$ $(c \equiv nLe^4/m_e^{1/2}T^{3/2}$; z, n are ion charge, ion density respectively).

1. Landau L.D. The kinetic equation in the Coulomb interaction case/ L.D. Landau // JETP. - 1937. V.7 - p.203-209