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O4.302 Theory of transport coefficients in Yukawa fluids (complex plasma)

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The purpose of this paper is to present simple and accurate practical expressions to estimate the viscosity and self-diffusion coefficients of three-dimensional Yukawa fluids in a wide parameter regime. The expression for the viscosity coefficient is based on a freezing temperature's scaling discussed recently by Costigliola et al. [1] in the context of dense simple fluids (LennardJones system, argon, methane, and liquid sodium). It is demonstrated that this scaling applies well to Yukawa systems, which allows estimation of the shear viscosity in a very extended range of temperatures, from the melting point to 100 times the melting temperature [2]. One of the recent approaches to the self-diffusion coefficient in strongly coupled Yukawa fluids [3] is briefly discussed. However, more attention is focused on the Stokes-Einstein (SE) relation. When self-diffusion of atoms in simple pure fluids is considered, the SE relation takes the form

D eta(Delta/T) = Alpha

where D is the self-diffusion coefficient, eta is the viscosity coefficient, Delta= n^(-1/3) is the mean interparticle distance, n is the particle density, T is the temperature (in energy units), and alpha is the SE coefficient. Theory predicts that the coefficient can be related to the properties of collective excitations [4], and expressed in terms of the longitudinal-to-transverse sound velocity ratio [5]. As a consequence alpha ~ 0.13 for soft long-range repulsive interactions, including Yukawa fluids as a representative example. Using existing numerical data it is documented that SE relation with 0.13 works extremely well for strongly coupled Yukawa fluids, providing a useful tool to estimate one of the transport coefficients when the other is known. Some aspects of the temperature dependence of the shear viscosity and diffusion coefficients on approaching the fluid-solid phase transition are discussed. The results are mainly intended for the field of complex (dusty) plasmas. However, relations to other related systems are pointed out, in particular, to the transport coefficients of liquid metals at the melting temperature.

References

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