Equation of state for weakly coupled quantum plasmas

J. Vorberger, M. Schlanges, W.D. Kraeft

Institut für Physik der Ernst-Moritz-Arndt-Universität Greifswald, 17487 Greifswald, Germany

Starting from quantum statistical theory [1] we establish a perturbation expansion for the equation of state of a quantum plasma in terms of the dynamically screened potential. In order to describe two component plasmas of any degeneracy, we restrict ourselves to systems of weak coupling and take into account terms up to order e^4 [2].

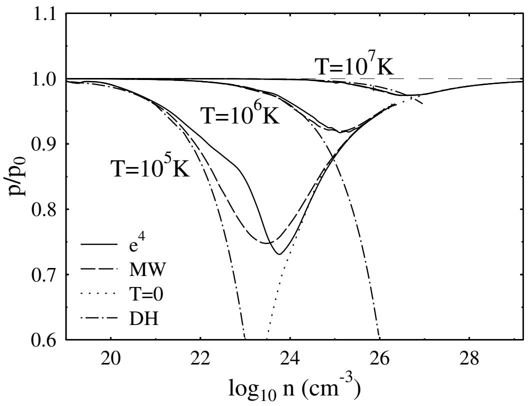

Figure 1: Isotherms of the pressure of an electron gas in units of the ideal pressure as function of the number density in different approximations.

Results for an electron gas are shown in figure 1. DH means the classical Debye–Hueckel correction, MW takes into account Hartree-Fock (HF) and Montroll-Ward (MW) terms, and the e^4 curve additionally accounts for exchange effects of order e^4 and represents the full expansion up to this order. The minimum behavior of the lines at intermediate density is due to nonideality effects. At higher and lower densities the curves approach unity what is caused by degeneracy effects at high densities and by large interparticle distances at low densities.

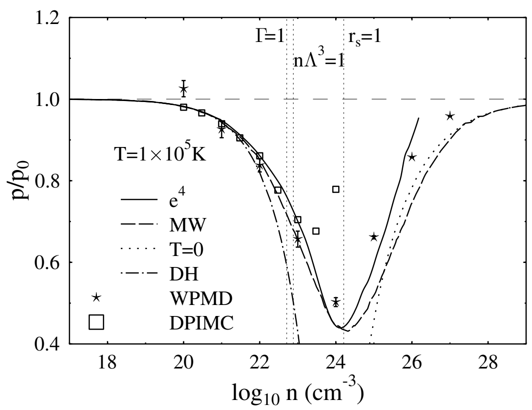

Figure 2: Pressure of a fully ionized hydrogen plasma in units of the ideal pressure as function of the number density at a temperature of $T = 10^5 K$ in different approximations. WPMD data from [3], DPIMC data from [4].

The pressure of fully ionized hydrogen can be seen in figure 2. The curves for hydrogen show, in principle, the same behavior as the curves in figure 1. We compare our results with results from first principle numerical simulations: Direct Path Integral Monte Carlo [4] and Wave Packet Molecular Dynamics [5]. As can be seen in this figure, at lower densities the agreement between the results is rather good. The results for depth and exact location of the pressure minimum strongly depend on the technique and thus on the approximation used.

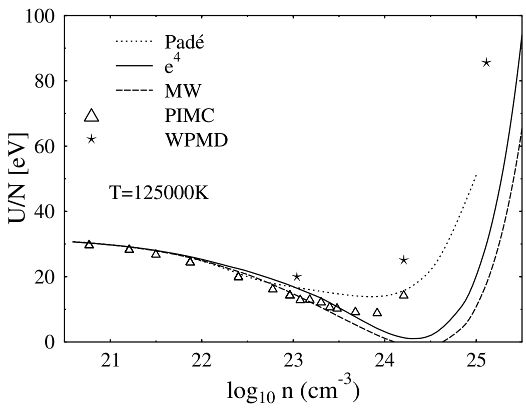

Figure 3: Internal energy of a fully ionized hydrogen plasma as function of the number density n at a temperature of $T = 1.25 \times 10^5 K$ in different techniques. WPMD data from [5], PIMC data from [6]. Padé means a Padé formula [1].

Nearly the same situation can be observed in figure 3 where the internal energy for hydrogen is shown. At intermediate and higher densities, where the coupling parameter becomes equal to or larger than unity strong electron–proton and proton–proton correlations occur. These correlations are not included in our approach.

References

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