WIGNER–SEITZ CELL MODEL AND THE PRESSURE IN CONFINED ONE-COMPONENT PLASMA

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The system of massive charged particles on the compensating uniform background is commonly termed one-component plasma (OCP). If the volume of such a system is confined to a sphere then the limited OCP or Coulomb cluster is formed. Here, the state of a system is defined not only by the Coulomb coupling parameter Γ but the number of particles N as well. The Coulomb clusters are most extensively studied both theoretically and experimentally in such fields as complex plasma, cold ion confinement, etc. It was found that such a system has significantly more complex structure than infinite OCP, namely, at $\Gamma \gg 1$, the Coulomb cluster is a system of nested spherical shells with or without a particle in the cluster center, depending on N. In [1], it was demonstrated that the assessment of Γ based on the Wigner–Seitz cell model is in close correspondence with the results of molecular dynamics simulation of the system, which indicates a good applicability of this model. In this report, the pressure in the Coulomb cluster at high Γ, when the cell model is most applicable, is estimated. Since the pressure of a compensating background is undefined in OCP, one can calculate solely the contribution of point charges. The cell model reduces a multi-body problem to a single-particle one, which enables one to estimate the virial and conclude that the pressure vanishes. An extension of the cell model is introduced that includes the correlation of the neighboring particle positions leading to oscillations of the cell center. A small parameter is then the ratio of the standard deviations for oscillations of the cell enter and a particle in the cell, or the interparticle correlation coefficient κ. It is demonstrated that in the first-order approximation, the compressibility factor of point charges is equal to κ^2. Thus, the pressure in a strongly coupled Coulomb cluster is positive and small.

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1. Shpil'ko E. S., Zhukhovitskii D. I. // Plasma Phys. Rep. 2023. V. 49. No. 10. P. 1207.