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Kinetic equation for Smoluchowski's diffusion

Smoluchowski's diffusion, [1], it is a diffusion in an external field is studied, and a general kinetic equation valid within the framework of classical statistical mechanics is found.

We apply Stecki's projection operator method, [2], to obtain a kinetic equation for an auxiliary distribution function f(k,v_1,t). This function yields the intermediate scattering function I_s(k,t), which is a Fourier transform of van Hove's function G_s(r,t). The function G_s(r,t) gives the probability of finding in a equilibrium system a given (marked) particle at (r,t), if it was known to be at the position r=0 at the time t=0. A kinetic equation of the convolution type for the time evolution of the distribution function f(k,v_1,t) is given.

Diffusion problems studied in the time scale comparable with time of particles collision lead to kinetic equations which for step-wise potentials are functional equations in the velocity space.

We start, as usually in statistical physics from Liouville's theorem, which is a key theorem in classical statistical and Hamiltonian mechanics. The gas is composed of N particles. We pay a particular attention to Lorentz' gas with N-1 immovable particles-scatterers, between which a light particle number 1 is moving, and to Brownian diffusion (one heavy–marked particle among N-1 light particles). The second case is a natural generalization of Smoluchowski's equation.

[1] Subrahmanyan Chandrasekhar, Mark Kac, Roman Smoluchowski, Marian Smoluchowski - his life and scientific work, ed. by R. S. Ingarden, Seria: Polish Men of Science, PWN - Polish Scientific Publishers, Warszawa 1999.

[2] Jan Stecki, On the kinetic equation nonlocal in time for the generalized self-diffusion process, Journal of Computational Physics 7 (3) 547–553 (1971).

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