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Isothermal Langevin dynamics in systems with power-law spatially dependent friction

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We study the dynamics of Brownian particles in a heterogeneous one-dimensional medium with a spatially-dependent diffusion coefficient of the form $D(x) \sim |x|^c$, at constant temperature. The particle's probability distribution function (PDF) is calculated both analytically, by solving Fick's diffusion equation, and from numerical simulations of the underdamped Langevin equation. At large times, the PDFs calculated by both approaches yield identical results, corresponding to subdiffusion for $c < 0$, and superdiffusion for $0 < c < 1$. For $c > 1$, the diffusion equation predicts that the particles accelerate. Here, we show that this phenomenon, previously considered in several works as an illustration for the possible dramatic effects of spatially-dependent thermal noise, is unphysical. We argue that in an isothermal medium, the motion cannot exceed the ballistic limit ($\langle x2 \rangle\ t^2$). The ballistic limit is reached when the friction coefficient drops sufficiently fast at large distances from the origin, and is correctly captured by Langevin's equation.

[1] S. Regev, N. Gronbech-Jensen, and O. Farago, Phys Rev. E **94**, 012116 (2016).

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