Fourth-order term effects in the Fick-Jacobs equation for diffusion in narrow channels

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In some situations, such as at high densities with long-range effects, diffusivity switching process approximations, or aggregation models, the diffusive flux does not adequately describe the system's behavior, so fourth-order terms terms help model slight deviations from standard Fick behavior. We study the effect of a fourth-order derivative term in the diffusion of Brownian particles confined to a narrow 2D channel whose longitudinal coordinate is larger than the transversal one. In these cases, a Fick-Jacobs-like equation is found using the projection method. It contains a third-order, in addition to the standard first-order entropic flux. It is shown that even at the lowest order, position-dependent modifications to the longitudinal diffusivity and the drift term appear, which also depend on a new scale related to the coefficient of the fourth-order term. Furthermore, using a simplified Kalinay-Percus method, the corresponding transport coefficients are obtained depending on the longitudinal coordinate and on the new scale. The linear or conical channel is analyzed to illustrate the results. Remarkably, although small, there are non-negligible effects due to the new scale. For instance, there is a region where diffusion is enhanced. Also the stationary solution is disscused.