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Thermal fluctuations of an interface near a contact line

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The effect of thermal fluctuations near a contact line of a liquid interface partially wetting an impenetrable substrate is studied analytically and numerically. Promoting both the interface profile and the contact line position to random variables, we explore the equilibrium properties of the corresponding fluctuating contact line problem based on an interfacial Hamiltonian involving a "contact"binding potential. To facilitate an analytical treatment, we consider the case of a one-dimensional interface. The effective boundary condition at the contact line is determined by a dimensionless parameter that encodes the relative importance of thermal energy and substrate energy at the microscopic scale. We find that this parameter controls the transition from a partial wetting to a pseudopartial wetting state, the latter being characterized by a thin prewetting film of fixed thickness. In the partial wetting regime, instead, the profile typically approaches the substrate via an exponentially thinning prewetting film. We show that, independently of the physics at the microscopic scale, Young's angle is recovered sufficiently far from the substrate. The fluctuations of the interface and of the contact line give rise to an effective disjoining pressure, exponentially decreasing with height. Fluctuations therefore provide a regularization of the singular contact forces occurring in the corresponding deterministic problem.

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