Manipulation and amplification of the Casimir force in systems with continuous symmetry: Exact results

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Casimir forces result from, and provide insight into, the behavior of a medium confined to a restricted space. In the case of the electromagnetic Casimir force the medium is the vacuum, and the underlying mechanism is the set of quantum zero point or temperature fluctuations of the electromagnetic field. The now widely-investigated critical Casimir force (CCF) results from the fluctuations of an order parameter and more generally the thermodynamics of the medium supporting that order parameter in the vicinity of a critical point.

One of the principal influences on the thermodynamic Casimir force, we will be dealing with, is the nature of the bounding surface. With respect to the CCF, published investigations have been focused, almost exclusively, on systems belonging to the Ising universality class. Here we present results aiming to close that gap by presenting results for systems with continuum symmetry of the order parameter. In order to do so, we review some recent and present some new both exact and numerical results for the behavior of the Casimir force in systems with a continuous symmetry and a film geometry with a finite extension L in one direction. We will consider the cases when the system is subjected either to surface fields or to twisted boundary conditions that induce helicity in the order parameter. We show that for such systems the Casimir force in certain temperature ranges is of the order of L^{-2}, both above and below the critical temperature of the bulk system. An example of such a system would be one with chemically modulated bounding surfaces, in which the modulation couples directly to the system's order parameter. We demonstrate that, depending on the parameters of the system, the Casimir force can be either *attractive* or *repulsive*. The exact calculations presented are for the one dimensional XY and Heisenberg models under twisted boundary conditions resulting from finite surface fields that differ in direction by a specified angle, the three dimensional Gaussian model with surface fields in the form of plane waves that are shifted in phase with respect to each other, and the spherical model under twisted boundary conditions. Where applicable, we will present results both for the transverse and the lateral Casimir force. Additionally, we present exact and numerical results for the mean field version of the three dimensional O(2) model with finite surface fields on the bounding surfaces. We find that all significant results are consistent with the expectations of finite size scaling. From the experimental point of view the different types of liquid crystals seem the best candidate to study the above mentioned effects. For such systems it is well known that director fluctuations in nematics induce long-range interactions between walls, which are attractive with symmetric boundary conditions, but may become repulsive with mixed ones. In smectics such forces are longer ranged than van der Waals ones.

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