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Casimir effects in 2D Dirac Materials

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Dispersive interactions originating from exchanged electromagnetic fluctuations play a prominent role in many materials and devices. This interaction is universal as it exists between any types of bodies, microparticles and atoms. Depending on the importance of the speed of light in the exchange process, one distinguishes between van der Waals ($c \to \infty$) and Casimir (c finite) regimes. Recent discoveries of novel nanostructured materials with nontrivial topology have brought new functionalities in the Casimir force, which further builds fundamental knowledge of light-matter interactions. In this review we give a detailed summary on recent developments of the zero point electromagnetic energy summation technique applied to Casimir and Casimir–Polder interactions involving 2D Dirac materials with emphasis on graphene. In addition to introducing the basic framework of this theory, theoretical advances in calculating the optical response in graphene using different models are also given. Key analytical and numerical findings for the Casimir and Casimir–Polder force are summarized including for composites with stacks of parallel layers. To broaden the perspective of this field we also present some recent results for Casimir interactions involving materials from the expanded graphene family, including silicene, germanene, and stanene, as well as Casimir friction in 2D Dirac systems. The theoretical approach based on calculating and summing the zero point electromagnetic modes is a powerful technique, which enables successful calculations of the Casimir and Casimir–Polder interactions involving a stack of finite number of graphene or other 2D layers. By summarizing and comparing different models for the optical response for graphene, a comprehensive understanding of important factors affecting the Casimir and Casimir–Polder forces are found. Specifically, the number of layers in the stack, chemical potential, temperature, and mass gap are shown how they affect the overall behavior of these forces in the context of the different models for optical response. Considering the different quantum phases in the expanded graphene family, Casimir force phase transitions driven by external fields are also found. Friction effects mediated by the exchange of electromagnetic fluctuations are also part of Casimir physics and again the Dirac energy structure is found to affect significantly the Casimir friction in graphene materials.

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