Comment on Repulsive Casimir Forces
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A recent theoretical calculation shows that the Casimir force between two parallel plates can be repulsive for plates with nontrivial magnetic properties. According to the authors, the effect may be observed with known materials, such as ferrites and garnets, and it might be possible to engineer micro- or nanoelectromechanical systems (MEMS or NEMS) that could take advantage of a short range repulsive force. Here we show that on the contrary the Casimir force between two parallel plates in vacuum at micron and submicron distance is always attractive.

The Casimir energy \( E \) per unit area of two infinite slabs of materials with permittivity and permeability \( \epsilon_{1,2}, \mu_{1,2} \) maintained at a distance \( a \) in vacuum is given by equation (4) of prl. To obtain equation (4), the authors parametrize the field modes using the vector \( \mathbf{k} = (k_x, k_y, k_t) \). In their notation, \( k_x \) and \( k_y \) are the components of the wave vector parallel to the plates, and \( k_t \) is defined by the Wick rotation \( k_t \leftrightarrow i\omega \), where \( \omega \) is the frequency. Integrating equation (4) over \( |\mathbf{k}| \) to obtain a simpler equation for \( E \), the authors implicitly assume that \( \epsilon_{1,2} \) and \( \mu_{1,2} \) do not depend on \( \omega \). From equation (7), the authors derive the following conclusions:

(i) When both materials have high \( \mu \) and \( \epsilon \), the sign of the force depends on the impedances of the materials.
(ii) When one of the two bodies is a perfect conductor, and the other has large \( \mu \) and \( \epsilon \), the sign of the force depends on the impedance of the latter.
(iii) In the uniform velocity of light (UVL) case, the sign of the force depends on the values of \( \mu \) of the two materials.

Finally the authors claim that a class of materials with high permeability might be suitable for a demonstration of the repulsive Casimir force, which could play a crucial role in the construction of MEMS and NEMS.

All the conclusions depend on the authors’ physically incorrect assumption that \( \epsilon_{1,2} \) and \( \mu_{1,2} \) are independent of \( k_t \).

While the assumption that \( \epsilon \) and \( \mu \) are independent of \( \omega \) is incorrect, one can examine the question whether in the range of frequencies which give the largest contribution to the Casimir force (corresponding to wavelengths \( \sim a \) this is indeed a reasonable approximation or not. The plate-sphere, cylinder-cylinder or plate-plate separations used in Casimir force measurements, as well as the typical distances between mechanical parts in MEMS and NEMS and those relevant to stiction problems, are in the submicron to micron range, corresponding to frequencies in the optical to mid-infrared region. In this spectral range definitely \( \epsilon \) cannot be assumed to be weakly dependent on frequency for most materials. Furthermore, concerning the hypothesis on \( \mu_{1,2} \), it can be shown from theoretical arguments that in the optical range the permeability of materials ceases to have physical meaning. In practice, no known material presents significant deviations from \( \mu = 1 \) in a much wider spectral range. As a consequence, for separations in the micron and submicron range, equation (4) becomes the usual Lifshitz formula, from which it follows that the Casimir force between is always attractive.

Interestingly another recent article shows that for two ferromagnetic slabs the magneto-optical Kerr effect gives rise to an additional attractive Casimir magnetic force. The result is obtained using an equation similar to equation (4) of prl. In this case, however, it is implicitly assumed that \( \mu = 1 \), and the force is calculated by only considering the dependence of the dielectric tensor on \( \omega \).

In conclusion we believe that the calculations presented in prl are not suitable for drawing conclusions on the sign and the magnitude of the Casimir force between real device elements at distances relevant to Casimir force measurements and to nanomachinery. At these distances the Casimir force between two slabs in vacuum is always attractive.

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references

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