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Reply to comment on 'No quantum friction between uniformly moving plates'

T G Philbin and U Leonhardt[1]
School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK
E-mail: ulf@st-andrews.ac.uk

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Abstract. We reply to the comment on our paper made by Volokitin and Persson (2011 *New J. Phys.* **13** 068001).

The comment [1] makes several assertions about the Casimir force between parallel plates with lateral relative motion, and what we regard to be an incorrect remark about the content of a preprint of ours. In fact, we contend that these authors have made a variety of contradictory claims about this problem, so that they present no coherent position to which a response can be addressed. This reply briefly deals with a few of the contradictions and errors that we believe exist in the comment.

The subject at issue is the quantum-vacuum, zero-temperature force between parallel plates with arbitrary constant lateral motion. A nonzero lateral component of this force is the definition of quantum friction. In support of the existence of quantum friction, the comment cites papers by its authors which are said to be 'accurate to order $(V/c)^2$', where V is the sliding velocity. But in [2] the same authors claim that zero temperature 'gives rise to a friction force, which depends cubically on sliding velocity'. Clearly, a calculation accurate to second order cannot predict a cubic-order force. This publication [2] also declares, in regard to the exact lateral force, that 'even without any detailed calculations it is clear that ... the p- and s-polarized waves [TE and TM waves] must give independent contributions to the friction'. We contend that this is a mathematical error, as one can see from the exact solution of the classical Green function [3]. The same error was also made in [4, 5] for the case of a normal relative motion of the plates. (To our knowledge, the problem of plates with normal relative motion is still unsolved.)

Contrary to what is stated in the comment, our preprint [6] makes no 'claim that maybe the Lorentz transformation for the stress tensor is not valid for the contribution to the stress tensor from quantum fluctuations'. An essential and subtle point in the calculations described in the

[1] Author to whom any correspondence should be addressed.

comment is the comparison of the quantum vacuum as seen by both plates. The definition of the vacuum state requires the division of the electromagnetic modes into those associated with creation operators and those associated with annihilation operators, a division that is normally equivalent to the division into positive and negative frequencies. But in the case of plates in relative motion, certain frequencies appear positive to one plate but negative to the other, and the correct division is required in order to find the limits on the frequency integrals in the Casimir-force expressions. This point is essential for correctly solving the problem but it is not mentioned in [7]. The comment fails to address this point directly, but it effectively argues that the issue can be avoided if one calculates the electromagnetic fields in the frame of one of the plates and then uses the result to calculate the stress tensor. This of course makes no difference to the issue, as one needs the correct expression for the vacuum stress in terms of the quantum electromagnetic field operators, which necessarily requires a solution of the same issue.

We do not further discuss this important point here since we believe the comment adds nothing to the discussion. As for quantitative results, we contend that the claims of these authors are contradictory [2, 4, 5, 7, 8] and we make no attempt here to catalogue and analyse them all.

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