Quantum Self-Propulsion of an Inhomogeneous Object out of Thermal Equilibrium

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Previously, we explored how quantum vacuum torque can arise: a body or nanoparticle that is out of thermal equilibrium with its environment, having a temperature T' different from that the the blackbody background, T, experiences a spontaneous torque. But this requires that the body be composed of nonreciprocal material, which seems to necessitate the presence of an external influence, such as a magnetic field. Then the polarizability of the particle has a real part which is nonsymmetric. This effect occurs to first order in the polarizability. To that order, no self-propulsive force can arise. Here, we consider second-order effects, and show that spontaneous forces can arise in vacuum, without requiring exotic electromagnetic properties. Thermal nonequilibrium is still necessary, but the body need only be inhomogeneous. We consider four examples: a needle composed of distinct halves; a sphere and a ball, each hemisphere being made of a different substance; and a thin slab, each face of which is different. The results found are consistent with previous numerical investigations. Here, we take into account the skin depth of metal surfaces. We consider the frictional forces that would cause the body to acquire a terminal velocity, which might be observable. More likely to be relevant is relaxation to thermal equilibrium, which can still lead to a readily observable terminal velocity. There also arises, in second order, a torque on a body out of equilibrium with its environment, provided the body be inhomogeneous and chiral. The resulting radiation fields reflect both the spontaneous force and torque.

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