Vacuum and thermal friction in rotating particles

Alejandro Manjavacas and F. Javier García de Abajo
Instituto de Óptica – CSIC, Serrano 121, 28006 Madrid, Spain
Email: ama@io.cfmac.csic.es

In this paper, we explore the thermal and vacuum electromagnetic friction [1] acting upon small rotating particles (see Fig.1a). Working in the framework of the linear response theory, our results are based in the application of the Fluctuation-Dissipation Theorem [2,3].

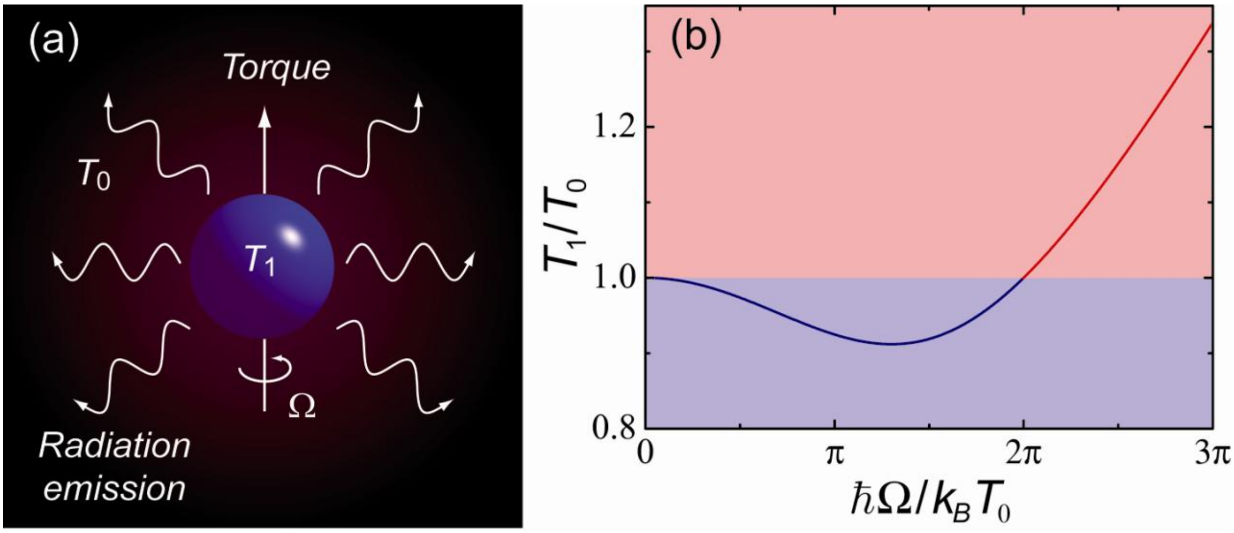

Figure 1. (a) System under study, consisting of an isotropic particle at temperature T_1 placed in vacuum at temperature T_0. The particle is rotating around the z-axis with an angular frequency Ω, and suffers an electromagnetic interaction with the surrounding radiation field. Due to this interaction the particle experiences a torque and radiates a net power. (b) Ratio between the particle and the environment temperatures as a function of the rotational frequency Ω. While for high rotational frequencies the friction leads to the heating of the particle, in the opposite limit the particle is cooled.

Assuming the dipolar approximation, we can characterize the EM properties of the nanoparticle through its polarizability. Within this formalism we are able to present analytical expressions for the net power radiated by the particle, as well as for torque exerted on it by the vacuum fields. Following from these results we compute the evolution of the internal energy of the particle, which allows us to describe the variations in its temperature during the friction process.
At zero temperature, vacuum friction transforms mechanical energy into light emission and particle heating. However, particle cooling relative to the background occurs at finite temperature and low rotation velocity (see Fig. 1b). Radiation emission is boosted and its spectrum significantly departed from the black-body emission profile as the velocity increases.
Finally, we illustrate our work with numerical examples, in which we study the dynamics of rotating particles placed in different environments (e.g., molecular clouds in outer space). In particular, we present results for the time needed for a particle to slow down its rotation to half the initial speed due to interaction with a thermal EM bath. Our study can be relevant in the design of nano-devices comprising rotating parts, as well as in the control of spinning nanoparticles.

Acknowledgments

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