Relaxation Time of Heat Bath and Thermal Conductivity

A. Iwaya and A. Suzuki
Department of Physics, Faculty of Science, Tokyo University of Science
1-3 Kagurazaka, Shinjuku-ku, Tokyo 162-8601, Japan.

Irreversible heat transfer unavoidably occurs in a system coupled to two heat baths at different temperatures. J.M.R. Parrondo and P. Español investigated such a system by using their ratchet model and showed that the mechanical link between the vanes and the ratchet implies these thermal baths are *not* necessarily isolated thermally [1]. This suggests there is an essential incompatibility between mechanical coupling and thermal isolation because in the model the mechanical coupling via fluctuations induces a heat transfer between the thermal baths.

To understand this mechanism, we investigate thermal conductivity of the model system. We consider a system coupled to two heat baths consisting of a gas at different temperatures T_1 and T_2. There is an axle with vane in each heat bath. As the vane is surrounded by the gas at a given temperature, it will undergo collisions with the molecules of the gas. Thus, the axle oscillates as a 1-dimensional Brownian rotor and its Brownian motion is characterized by temperature and friction constant of each heat bath. A mechanical link between two heat baths is described by a potential energy $\frac{1}{2}k(x_1 - x_2)^2$, where k is a coupling constant of axles and x_1, x_2 are respectively the angle of each axle. This mechanical coupling induces a heat transfer even in a case where two heat baths never correlate directly. If the total system are thermally isolated from any other environment, temperature of heat baths would change by heat transfer. To investigate such a situation, we consider the thermal conductivity by taking into account a relaxation time which characterizes the behavior of a heat bath. We will show a thermal conductivity as a function of the relaxation time and discuss the relation between the relaxation time and the temperature of heat bath.

References

[1] J. M. R. Parrondo and P. Español, Am. J. Phys. **64** (1996) 1125.