IL TEOREMA

Aspetti "filosofici"

Fluttuazioni spontanee di quantità microscopiche di un sistema all'**equilibrio** sono descritte da opportune ***funzioni di correlazione*** $C_{AB}(\boldsymbol{x},t)$ di variabili dinamiche (e.g. $\boldsymbol{x}_\alpha(t)$, $\boldsymbol{v}_\alpha(t)$, $\rho(\boldsymbol{x},t)$,…)

La **risposta lineare** ad una (debole) perturbazione esterna e le relative ***suscettività*** sono descritte dalle ***stesse funzioni di correlazione*** che descrivono le fluttuazioni termiche del sistema imperturbato.

Teorema di Fluttuazione-Dissipazione
(Callen, Welton - 1951)

Fluttuazioni spontanee e il loro modo di attenuarsi (all'equilibrio) sono governate dagli stessi processi dinamici che regolano le fluttuazioni indotte e la risposta ad una sonda

Il teorema di Callen-Welton stabilisce la "misurabilità" di ***proprietà dinamiche di equilibrio*** (i.e. delle relative funzioni di correlazione) attraverso l'interazione con un campo esterno e, in particolare, con una sonda attraverso 'perturbatrici' **misure di scattering**

The fluctuation–dissipation theorem . . . (Callen and Welton, 1951)

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. . . and Ryogo Kubo dissemination of its basic concepts

mirror is driven by a suitable electromagnetic device such as is used for galvanometers. Such a forced motion always suffers from a friction or a resistive force. It results from impacts of molecules on the particle or the mirror. Although molecular collisions are random, a number of the collisions produce a systematic result proportional to the velocity of the particle or the angular velocity of the mirror.

Thus random impacts of surrounding molecules generally cause two kinds of effect: firstly, they act as a random driving force on the Brownian particle or the mirror to maintain its incessant irregular motion, and, secondly, they give rise to the frictional force for a forced motion. The first is the *systematic* part of the effect and the second is the *random* part. This in turn means that the frictional force and the random force must be related, because both come from the same origin. This internal relationship between the systematic and the random parts of *microscopic forces* is, in fact, a very general matter, which is manifested in the so-called *fluctuation–dissipation theorem*.

As we shall see in the following, this theorem states a general relationship between the response of a given system to an external disturbance and the internal fluctuation of the system in the absence of the disturbance. Such a response is characterized by a response function or equivalently by an admittance, or an impedance. The internal fluctuation is characterized by a correlation function of relevant physical quantities of the system fluctuating in thermal equilibrium, or equivalently by their fluctuation spectra. The fluctuation–dissipation theorem can thus be used in two ways: it can predict the characteristics of the fluctuation or the noise intrinsic to the system from the known characteristics of the admittance or the impedance, or it can be used as the basic formula to derive the admittance from the analysis of thermal fluctuations of the system. The Nyquist theorem is a classical example of the first category (Nyquist 1928), whereas, perhaps, Onsager's proof of the symmetry of kinetic coefficients is the oldest example of the second (Onsager 1931).