Measuring out of equilibrium fluctuations

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As a general statement the chapter will be mainly oriented towards experiments in systems where fluctuations cannot be neglected. The case of chaotic systems will be only briefly discussed. I will try to skip complex mathematical proofs, summarizing only the main results which can be tested in experiments. Specifically I would like to discuss :

1) **The harmonic oscillator driven out of equilibrium**
We describe here the simplest experimental systems that one may construct, which is the base for many physical systems, this the harmonic oscillator driven out of equilibrium by an external force. We discuss the fluctuations of the injected and dissipated power, which may lead to instantaneous violations of the second principle of thermodynamics. A simple theory based on second order Langevin equation and on several inputs from experiments will be introduced to justify the experimental observations. This is interesting because is a development that can be followed by any student in Physics without knowing much about complex mathematical theories.

2) **Two other systems: the electric circuits and the Brownian particle in a optical trap**. These are systems which are described by a first order Langevin equations. The advantage here is that in the case of the Brownian particle we can introduce non-linear potentials and show that many concepts can be used in the non linear case where the linear response function is not even defined. The case of stochastic resonance will be also discussed. These are very important examples for real applications.

3) **The entropy production rate**
We discuss here the various entropies which have been introduced in literature to describes the energy exchanges with the heat bath when the external injected energy is of the order of the thermal energy. More emphasis will be given to experimental tests of these idea and what actually we learn from them.

4) **Determine the equilibrium free energy using out of equilibrium.**
This is one of the most useful applications in the study of equilibrium fluctuations of the injected power. We are talking about the Jarzinky and Crook equalities. We will consider first the harmonic oscillator and than we will take examples from biology.

5) **Can we know the direction of time in out of equilibrium system ?**
I will describe these measurements only if Gaspard and Andrieux will not treat this. We discuss here the fact that in a dissipative system one can actually find the direction of the arrow of time by looking at the time series of the fluctuations of the injected power. This technique can actually be used to compute the entropy production rate.

6) **The linear response function and fluctuations out of equilibrium**
We discuss here the newly proposed form of Fluctuation Dissipation Theorem which can be used out of equilibrium. This is a tricky and interesting point with thousands of potential applications and cannot be neglected in a book like this. Furthermore there are already experiments on this subject, thus they merit to be discussed.

7) **The random forcing**
This is an important and widely discussed problem which merits to be described in the book. Without pretending to give a definitive answer we can show a few experimental results which give an idea of the phenomenology involved with such a kind of forcing when the variance of the forcing is larger than than those induced by thermal energy.