Various kinds of heats in interacting system and bath

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We investigate various kinds of heats produced in sytem and bath coupled via interaction Hamiltonian. We define $Q_{\rm S}$ and $Q_{\rm B}$ as the energy loss of system and the energy gain of bath, respectively, caused by the change of interaction Hamiltonain in dynamics. We consider bath with a thermostat which prevents it from heating up indefinitely so as to reach equilibrium or nonequilibrium steady state. Then, we define another kind of heat $Q_{\rm SB}$ as the energy dissipation of bath towards super bath surrounding it. The three quantities are equal only in average sense for steady state, but different in transient or time-dependent state. It is contradictory to our common sense of the equivalence of $Q_{\rm S}$ and $Q_{\rm B}$. We study a model with a single system particle interacting with neighboring bath particles via harmonic potentials. Then, we show the distribution functions of thermal fluctuations for the three heats to manifest drastic difference rather than similarity, even in steady state. We find that fluctuation theorem for entropy production is not uniquely expressed unlike the result derived by the usual master equation approaches. Two forms of fluctuation theorems are possible, depending on the choice of heat as either $Q_{\rm S}$ or $Q_{\rm B}$, which are shown to relate with the distance measure of two well-known guesssed density functions for system and bath from a true one.