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Testing Landauer's Principle in a Feedback Trap

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Landauer's principle, formulated in 1961, postulates that irreversible logical or computational operations such as memory erasure require work, no matter how slowly they are performed. For example, to "reset to one" a one-bit memory requires at least kT ln2 of work, which is dissipated as heat. Bennett and, independently, Penrose later pointed out a link to Maxwell's demon: Were Landauer's principle to fail, it would be possible to repeatedly extract work from a heat bath.

We report tests of Landauer's principle in an experimental system consisting of a charged colloidal particle in water. To test stochastic thermodynamic ideas, we create a time-dependent, "virtual"double-well potential via a feedback loop that is much faster than the relaxation time of the particle in the virtual potential. In a first experiment, the probability of "erasure"(resetting to one) is unity, and at long cycle times, we observe that the average work is compatible with kT ln2. In a second, the probability of erasure is zero; the system may end up in two states; and, at long cycle times, the average measured work tends to zero. In individual cycles, the work to erase can be below the Landauer limit, consistent with the Jarzynski equality. Finally, in asymmetric wells, the different well sizes can allow for erasure with an average cost below kT ln2.

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