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High-Precision Test of Landauer's Principle in a Feedback Trap[1]

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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.

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