Researchers prove Landauer was right in saying heat is dissipated when memory is erased

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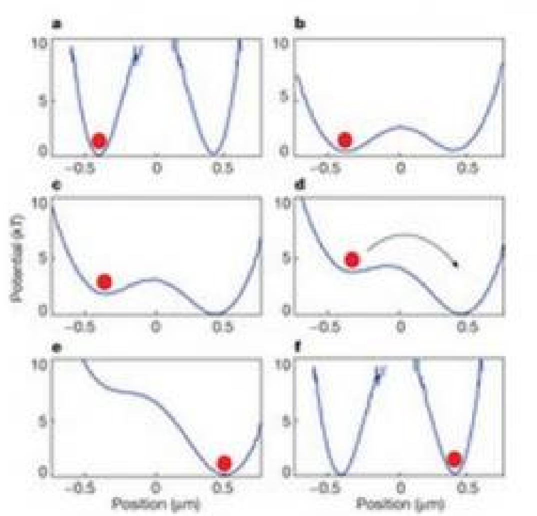

The erasure protocol used in the experiment. Image: [i]Nature[/i] 483, 187-189 (08 March 2012) doi:10.1038/nature10872

(PhysOrg.com) -- For over half a century, physicists and computer scientists have been troubled by a theoretical concept set forth by Rolf Landauer. He suggested that the very act of erasing a bit of memory in a digital system causes heat to be dissipated. This little idea has bothered researchers for two reasons. One is because if true, it will mean there will come a time within the next couple of decades when fabricated memories will reach a point where they cannot be made any smaller due to the heat that will be dissipated when memory is erased. The other reason is because until now, no one has been able to prove whether it was really true or not; now all that has changed, much to the dismay of computer engineers. Eric Lutz and his colleagues at the University of Augsburg in Germany have devised an experiment that proves that Landauer was right. They have published their findings in the journal *Nature*.

To settle the matter once and for all, Lutz and his team constructed a memory device using a very tiny floating glass bead and two equally tiny side-by-side wells for the bead to sit in. If the bead sat in the left well, that represented a “O” state, if in the right one it was a “1”. To change the state, a small barrier between the two was lowered and the surface in which they sat was tilted allowing the bead to roll into the opposite well. The wells in this case were actually optical tweezers that were able to hold the beads in place using lasers. The memory device was erased by putting the bead back in its original state. Then because the memory device was too small to be able to record if any heat was dissipated when the memory device was reset, or erased, the team measured instead the speed at which the bead moved between the two wells which allowed them to calculate the heat that was given off. And lo and behold, it turned out to match Landauer’s original predictions.

Landauer came to make his prediction to refute Maxwell’s demon, named for 19th century scientist James Clerk Maxwell who dreamed up the idea of a tiny demon that could separate hot molecules from cold then create a machine that ran based on the heat flowing from one to the other; in essence a perpetual motion machine. Such a system would of course violate the second law of thermodynamics because as we all know, you can’t get something from nothing. Landauer suggested that energy would have to be expended as the system was reset (its memory erased) which would balance out the energy created, proving what everyone knew intuitively all along.

More information: Experimental verification of Landauer's principle linking information and thermodynamics, *Nature* 483, 187–189 (08 March 2012) [doi:10.1038/nature10872](https://doi.org/10.1038/nature10872)

Abstract
In 1961, Rolf Landauer argued that the erasure of information is a dissipative process. A minimal quantity of heat, proportional to the thermal energy and called the Landauer bound, is necessarily produced when a classical bit of information is deleted. A direct consequence of this logically irreversible transformation is that the entropy of the environment increases by a finite amount. Despite its fundamental importance for information theory and computer science, the erasure principle has not been verified experimentally so far, the main obstacle being the difficulty of doing single-particle experiments in the low-dissipation regime. Here we experimentally show the existence of the Landauer bound in a generic model of a one-bit memory. Using a system of a single colloidal particle trapped in a modulated double-well potential, we establish that the mean dissipated heat saturates at the Landauer bound in the limit of long erasure cycles. This result demonstrates the intimate link between information theory and thermodynamics. It further highlights the ultimate physical limit of irreversible computation.

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