New scientist information

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For at its heart, information is a mystery bound up with thermodynamics.

A crucial result came in 2008, from Takahiro Sagawa and Masahito Ueda at the Tokyo Institute of Technology. They worked out that you can salvage the second law by adding an extra term called mutual information (Physical Review Letters, vol 100, p 080403). This is a measure of how much the demon knows about whatever system it is looking at. “You can think of the measurement as a correlation between the system and an apparatus or memory,” says Juan Parrondo, who studies the thermodynamics of information at the Complutense University of Madrid, Spain.

Sagawa and Ueda’s updated second law shows how much work you can extract from a system for a given amount of demonic knowledge.

One consequence is that blank memory can be a kind of fuel, an idea described in 2012 by Chris Jarzynski and Dibyendu Mandal at the University of Maryland, College Park.

That blank memory could simply be a paper tape bearing a long string of zeros, although to do anything meaningful you would need a lot of them: 300 billion billion zeros allow the demon to lift an apple by 1 metre.

Jukka Pekola and his team at Aalto University in Espoo created a microscopic demon of chilling and powerful simplicity. Their set-up, originally suggested by Massimiliano Esposito at the University of Luxembourg and his colleagues, is based on two quantum dots, devices that can briefly trap single electrons. One is known as the system, the other is the demon. The demon usually holds an electron, loosely. When an electron reaches the system, it repels and ejects the demon’s electron electrostatically. This process robs the system electron of some potential energy, which means that when it leaves the quantum dot it must use up some of its thermal energy to do so. The result is that it arrives in the wires cooler than when it left (see diagram).

If information alone can have a physical effect, then it is a physical thing. So what kind of thing is it? There are two ways of looking at it. One is to consider information

as a form of entropy, the quantity in thermodynamics that expresses disorder. In Maxwell’s thought experiment, that equates to how mixed up the molecules are. The more disordered they are, the more information the demon must have to do its job.

Another way to think of information is as a kind of energy catalyst: it enables you to convert the chaotic energy of heat to the useful energy of work.

although Pekola’s demon involves single electrons, they are constrained to behave mostly like classical particles that don’t exhibit the strangest features of the quantum world.

Pekola’s demon is not going to bring us perpetual motion. It is still governed by the restrictions Landauer hit upon: it can create a temperature difference that could be used to do work, but only at the cost of repeatedly wiping its memory, which requires work.