Focus: A Thermostat that Consumes No Energy

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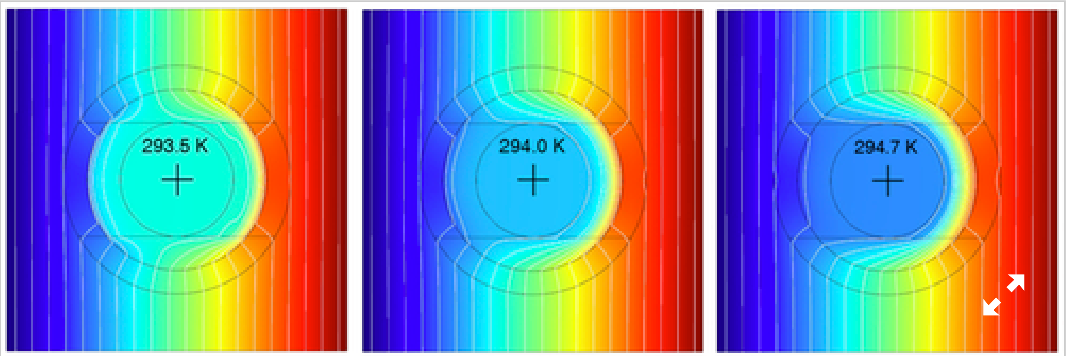
Experiments show that a region next to changing hot and cold areas can be maintained at a fixed temperature without consuming energy.



X. Shen *et al.*, Phys. Rev. Lett. (2016)

Keeping its cool. Simulations show that the energy-free thermostat maintains a constant temperature within a desired zone, despite a changing external temperature environment. Here the geometry is a 2-dimensional "thermal cloak," rather than the 1-dimensional arrangement of the basic theory, and regions whose thermal conductivities depend on temperature in several different ways surround the central zone. The images show the temperature distributions with the left boundary in each case held at 273.2 K, while the right boundary increases in temperature from left to right: 323.2 K, 338.2 K, and 353.2 K. Despite this increase of 30 K, the temperature within the central zone changes by no more than 1.2 K. **Show less**

Maintaining stable temperatures is important in electronic chips and building interiors, and it usually requires energy for heating or cooling. Yet a group of Chinese physicists has now demonstrated how to control the temperature in a region surrounded by changing hot and cold areas without using additional energy. The idea is to enclose the region with materials whose thermal properties change with temperature. The team showed that, without consuming energy, the central region of a metallic strip stayed at a constant temperature despite heating one end by 30 degrees. The researchers believe their concept can be developed into an energy-saving system for practical use.

Keeping a fixed temperature inside a house with one side shaded and the other side exposed to both morning and noontime sun would normally require significant cooling energy. Similar temperature control problems, within devices with large temperature differences that change over time, also arise in electronics and aircraft engines.

To address such problems, Jiping Huang of Fudan University in Shanghai and his colleagues propose an energy-free thermostat. They imagine a small zone at temperature T between two beams extending in opposite directions, one whose far end is cold, the other hot. The challenge is to prevent the central zone from heating or cooling as the temperatures of the far ends of the beams vary.

The team's scheme exploits the possibility that the heat conductivity of a material—a measure of how easily heat flows through it—can vary with the material's temperature. As they show mathematically, the cold beam material needs to be chosen so that it conducts heat well at temperatures above T and poorly at temperatures below T. The hot beam should have the opposite properties. Solving the heat flow equations, the team shows that the temperature within the central zone will then remain nearly constant at temperature T as the temperature of, say, the hot end is raised.

Huang and his colleagues require that the total rate of heat flow from hot to cold remains unchanged as the hot end warms, so no energy is added or removed. One might expect that as the hot side becomes hotter, the central region would also heat up. Instead, the hot beam's heat conductivity drops, which has the effect of increasing the temperature difference between the hot end and the central zone. As with electric wires or water pipes, when the resistance to flow through a channel increases, the difference in voltage or pressure across the channel also goes up, assuming the flow rate is fixed. For heat flow, the analogy implies an increased temperature difference, which in this case is just enough to maintain the central zone at temperature T.

The researchers also demonstrated the idea in an experiment, trying to keep a constant temperature in the central zone of a thin metallic strip with variable hot and cold temperatures applied to its ends. To make the conducting beams, they constructed composite structures using two layers built of interlocking lateral strips of different materials. One layer of strips was fixed in place and able to conduct heat weakly; the other layer of strips involved a material that bends upward when the temperature changes, breaking the conduction path and leaving only the lower-conductivity layer. In experiments using thermal imaging, the researchers found that when the temperature of the hot end was increased from 320 to 353 K, the temperature in the central zone went up by only 1 degree.

Huang expects the idea to find commercial uses quite soon, especially in efforts to reduce energy consumption. For home temperature control, for example, materials with the appropriate temperature-dependent conductivity applied to the exterior surfaces of homes could reduce the need for air conditioning. He suggests that the concept could also work for satellites—a spacecraft can develop huge temperature differences between its Sun-facing side and other parts of the craft.

"This idea is quite novel and sophisticated," says Cheng-Wei Qiu of the National University of Singapore. "It has great potential for real application in situations where the environmental temperatures on two sides of some object change," he says, adding that this approach for temperature regulation in homes is "quite promising."

This research is published in ***Physical Review Letters***.

–Mark Buchanan

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Subject Areas

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Temperature Trapping: Energy-Free Maintenance of Constant Temperatures as Ambient Temperature Gradients Change

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