How to chill an object by sending its heat into space

Scientists demonstrate a cool new technique for getting rid of unwanted warmth

Solar panels collect energy from space. Now researchers have built a device that works in reverse: It cools an object by radiating its energy into outer space.

When a refrigerator cools your food, it takes the heat away and dumps it into your kitchen. That adds to your home's cooling bills. Likewise, when your air conditioner cools your home, it sends that heat outdoors. It also makes things warmer for everyone else in your neighbourhood. The farther away you can send heat, the better. And there's not much farther you can send it than outer space. Now, researchers have built a device to do just that. It cools down an object by *radiating* its heat directly into space.

For now, the device isn't too practical. But its designers say that such cooling methods, combined with other techniques, might one day help people get rid of unwanted heat.

Radiation is the means by which electromagnetic waves carry energy from one place to another. This energy might be starlight traveling through space. Or it could be the heat of a campfire warming your hands.

The bigger the temperature difference between two objects, the quicker that heat energy can radiate between them. And not many things are colder than outer space, notes Zhen Chen

Outside the envelope of gases surrounding Earth — our *atmosphere* — the average temperature of space is about –270° Celsius. Chen and his team wondered if they could take advantage of this big temperature difference between Earth's surface and outer space to cool an object on Earth, using radiation.

[Explainer: Understanding light and electromagnetic radiation]

For an object on Earth to shed energy to space, radiation must travel through the atmosphere. The atmosphere doesn't let all wavelengths of radiation through, Chen points out. But certain energy wavelengths can escape with little resistance.

One of the atmosphere's clearest "windows" is for wavelengths between 8 and 13 micrometers (millionths of a meter) At these wavelengths, electromagnetic radiation is invisible to the human eye. Fortunately, says Chen, objects at about 27 °C radiate much of their energy in just that window.

Building a heat-emitting device

To study the new concept, Chen's team built an object they would try to cool. They used mostly *silicon.* The basic ingredient in beach sand, silicon is both cheap and sturdy.

In a new cooling device, a shiny layer of aluminium (bright layer at bottom) and a coating of silicon nitride (top surface) help radiate heat from a layer of silicon (middle) into space.

Radiation isn't the only way objects can transfer energy. Another way is *conduction.* It happens as atoms move around and bump into one another. During this natural jostling, warmer atoms transfer some of their energy — heat — to colder atoms.

[Explainer: How heat moves]

To minimize energy transfer through conduction, Chen and his team built a special chamber to hold their disk. Inside, they placed the disk on top of four small ceramic pegs. The result was kind of like a tiny table. Ceramics do not conduct heat well. So with this design, very little heat could move from the disk to the chamber floor through conduction.

The researchers also wanted to minimize heat loss through *convection*. That's where an object transfers heat to the air around it, allowing the air to move and actually carry and transfer heat to colder regions. To make sure that their disk's heat wouldn't be lost by convection, Chen's team sucked all the air out of the chamber.

The only remaining way for the object to lose heat was through radiation.

An "extreme experiment"

The team tested its device on the roof of their building at Stanford. Some of those tests spanned a full 24 hours. The object's heat energy successfully disappeared into space. This radiant loss of heat could cool their object by an average of 37 degrees C.

A cooling system that sends an object's heat energy into space could someday aid other cooling techniques

As Chen expected, moist air in the atmosphere reduced the system's effectiveness. His team had known that water vapour blocks some radiation in the normally clear 8-to-13-micrometer window. But the cooling indeed was efficient when the humidity was low.

The cooling device the team built isn't exactly a useful refrigerator. For one thing, the object the team cooled is small and specially designed. If the team instead tried to cool something like a can of drink, "it would take them a long, long time"

"It's hard to see how this could be a primary method of dumping energy," Austin Minnich agrees. He's a materials scientist at the California Institute of Technology in Pasadena. In other words, a cooling device like the team's prototype might not be able to cool something all by itself. But it could help out other types of cooling systems, Minnich suggests.

That extra help might be a little bulky, though. For one thing, he notes, to radiate energy at the same rate as a 100-watt light bulb, engineers would need to build a surface of about 1 square meter. That's about the same size as some rooftop solar panels.

Chen acknowledges that the team's cooling device is small. And sometimes engineers have problems making experimental devices work when they try to enlarge them. One challenge to making the heat-shedding device bigger is that the chamber it's in needs to be airless (a vacuum). Sucking all the air out of a larger chamber without making its walls crumple is tricky.

1/ Describe and explain what happens to the temperature of your kitchen if it has a refrigerator working in it. The doors of the refrigerator are closed. (3)

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2/ What does an air conditioner do with the heat it takes from inside your house? (2)

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3/ How does the energy collected by the solar panels travel through space (2)

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4/ What would you estimate the average temperature on the surface of the Earth to be? (1)

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5/ What would you estimate the difference between the average temperature on the surface of the Earth and Outer space to be? (3)

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6/ Compare and contrast conduction and convection as two methods of heat transfer. (4)

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7/ How does a moist atmosphere make the cooling less efficient. (2)

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8/ What is meant by a 'primary method of dumping energy'? (3)

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9/ What surface area would the device need to radiate 300W of energy (1)

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10/ What is the problem with sucking all the air out of a large chamber? (1)

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