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KNOWLEDGE ABOVE ALL

QUANTUM

BY SHREEYESH S.

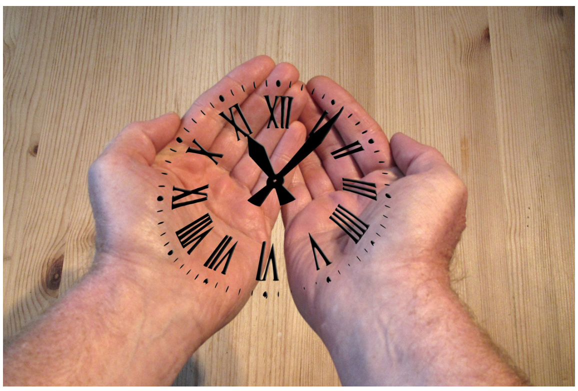
COULD TIME FLOW IN REVERSE? SURE THING, QUANTUM PHYSICISTS SAY

Isaac Newton's picture of a universally ticking clock more or less sums up how we understand time: the arrow of time only moves forward, cruelly robbing us of the chance to revisit our past.

Not everyone takes that for granted though, as evidenced by Albert Einstein, whose 1905 theory of special relativity stated that time is an illusion that moves relative to an observer. Today, physicists like Julian Barbour, who has written a book on the illusion of time, say change is real, but time is not; time is only a reflection of change. And just last week, a team of physicists published a new paper suggesting that quantum systems can move both forward *and* backward in time.

To understand why scientists previously established that time knows only one direction—forward—we need to examine the second law of thermodynamics. It states that within a closed system, the entropy of the system (that is, the measure of disorder and randomness within the system) remains constant or increases. If our universe is a closed loop, curled up like a ball, its entropy can never decrease, meaning the universe will never return to an earlier point. But what if the arrow of the time looked at phenomena where entropy changes are small?

"Take the case of a gas in a vessel," says Giulia Rubino, a postdoctoral research fellow at the University of Bristol, and lead author of the new paper that appears in Communications Physics. "Let's suppose that at the beginning, the gas occupies only half of the vessel. Then imagine that we remove the valve that confined it within half of the vessel so that the gas is now free to expand throughout the vessel." "Associating the arrow of time with entropy or a quantum mechanical system collapsing (as it is stated in the paper) are not formal statements, but popular methods that are easy to use," he says. Even that time evolves forward is not an axiom per se, but a theory that astrophysicist Arthur Eddington coined and popularized in 1927. "That these ideas are used does not make them the truth. When we forget the real, underlying physics [the universally accepted axioms], we come up with all sorts of crazy things," Podila says. So maybe it is time (and not space) that is the final frontier, despite what the beloved Captain James T. Kirk repeated at the beginning of each Star Trek episode. Or, perhaps spacetime, the idea that space and time fuse together into one interwoven continuum, is. Ever since Einstein formulated his theory of relativity, we stopped perceiving space as a three-dimensional figure and time as a one-dimensional one. "Time became the fourth element of a four-dimensional vector that describes space and time," says Rubino. It's a unified, dynamic entity we are still scratching our heads over.



GOOGLE MAY HAVE CREATED AN UNRULY NEW STATE OF MATTER: TIME CRYSTALS

MANDAR KOLI-
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Scientists from around the world claim to have harnessed a time crystal inside a quantum computer. If true, their discovery—as outlined in a July 28 pre-print research paper—could change the world virtually overnight with a limitless, rule-breaking source of energy that would bring quantum computers into the now.
As *The Next Web* astutely points out, this could be "the most important scientific breakthrough in our lifetimes." But to understand why, let's first examine the complicated connection between time crystals and quantum computing.

A time crystal is a special phase of matter that changes constantly, but doesn't ever appear to use any energy. This, scientists say, means it violates Isaac Newton's first law of motion, which deals with inertia—the resistance an object has to a change while in motion. A rolling marble doesn't stop unless other forces act upon it, for instance. But from experience, you know that it will eventually stop due to forces like friction. If your marble were a time crystal, though, it would literally never stop. For this research—which, notably, has not yet been peer-reviewed for publication in an academic journal—a group of over 100 scientists from around the world collaborated with Google Quantum AI, a joint initiative between Google, NASA, and the nonprofit Universities Space Research Association. Its goal is to expedite research on quantum computing and computer science.
In the paper, the scientists describe building a special microscopic rig where a time crystal is surrounded by superconducting qubits—special particles that are the bread and butter of quantum computing.
The quantum computer sits inside a cryostat, which is a temperature-controlled supercooling chamber that keeps all the materials at the right, extremely low temperature for advanced states like superconducting or time crystals (nuclear fusion also relies on cryostats as a way to keep equipment at the right temperature for containing fusion's extraordinary heat). It's not surprising that Google is leading the charge toward powerful quantum computing, themselves named after the mathematical term for a 1 followed by 100 zeros: a googol. But what will come of one of the world's largest and most omnipresent companies having the most cutting-edge computing technology ever seen? It might take a time crystal-powered quantum computer to make that prediction.

HOW TO BUILD A PARTICLE COLLIDER ON THE MOON—AND WHY WE SHOULD

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Particle colliders propel charged particles like protons and electrons together at high speeds. On Earth, some are circular, like the Large Hadron Collider (LHC) in Geneva, Switzerland. Others are built in straight lines. Both designs help particles reach phenomenal speeds.

The energy from the collisions can create matter in the form of new particles, including some of the largest ones that we know of (like the Higgs boson, a fundamental particle that helps give other particles mass). So having the extra space to build a bigger, more powerful particle collider could potentially lead scientists to the discovery of other new particles. These particles help to glue together disparate physics ideas and move us toward a more complete understanding of the universe. A megastructure on the moon, for its part, could enable particle acceleration that reaches 14 quadrillion electron volts, or about 1,000 times more energy than the LHC—the most powerful particle collider on Earth.

STEP 1:

Send the workforce to the moon for surveys. First, scientists will need to see what materials are available on the moon—and what they'll need to bring from Earth. The collider could use regular, supercooled magnets or "higher-temperature"

STEP 2:

Consider how the collider will wrap around the moon. You can take the circumference of a spheroid at any point or location, so the collider doesn't have to wrap around the widest part of the moon.

STEP 3:

Set up manufacturing infrastructure. Initially, mining for materials will be the highest priority. "The best option for a moon-based collider would be to use iron-based, high-temperature superconductors because it looks like the moon is full of accessible iron," Beacham says.

STEP 4:

Bore out tunnels for the collider. Beacham says the moon's surface temperature variations are an immediate problem. An array of superconducting magnets will partly power the particle collider, so the entire structure must be temperature-controlled.

STEP 5:

Determine a power source. The collider will require so much energy that even all of the existing nuclear fission power on Earth—which supplies about 10 percent of our total energy production—wouldn't suffice.

HOW TO CONQUER THE VIRAL MILK CRATE CHALLENGE, ACCORDING TO SCIENCE

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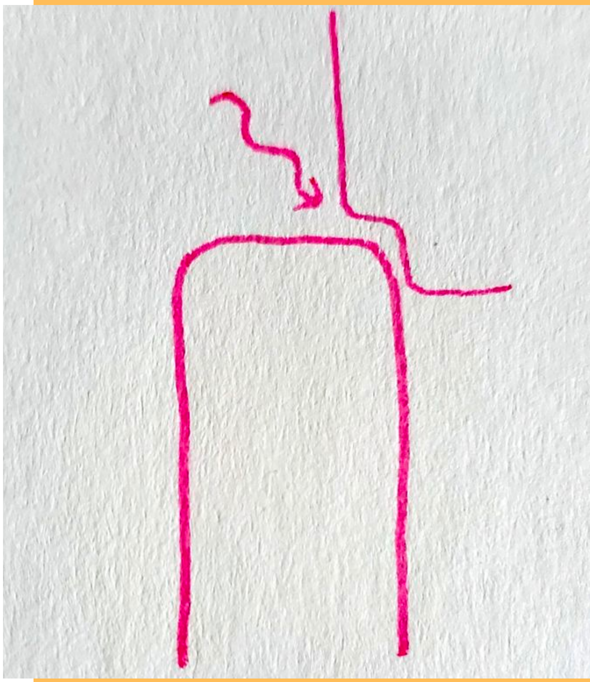
There's always a new viral sensation online, and this week, it's something called the "milk crate challenge." What is it, and why are people falling from towering stacks of milk crates for attention? The explanation requires a little bit of speculative physics and psychology.

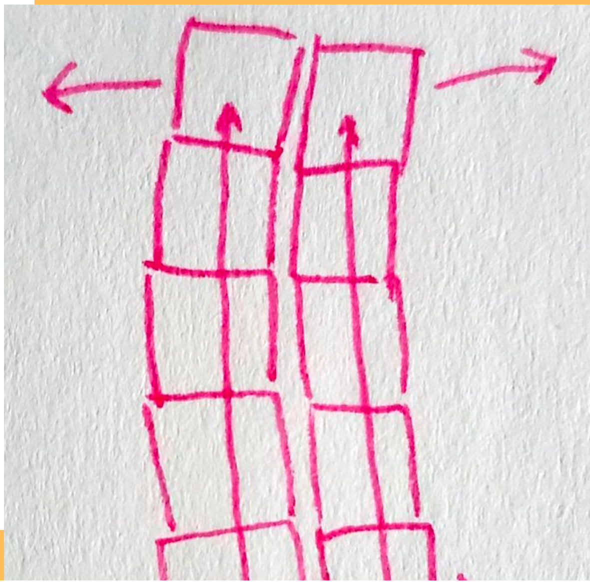
To complete the milk crate challenge, you need 49 milk crates—not so many for those who live near a grocery or corner store where they tend to accumulate. You stack the milk crates into a pyramid-shaped set of "stairs" that reach up to seven milk crates high at the tallest point, and then attempt to walk up and down the entire structure.

It seems easy at first glance, but as you climb, the highest levels of the pyramid quickly start to shift around, at which point the climber may panic a bit and step too fast or too off-center. Thankfully, most videos show this happening over grass, and not concrete; most of the videos end in hilarious fails that could otherwise be dangerous.

So let's zoom in on what's happening here in more detail. First of all, what's the deal with the ubiquitous containers we call milk crates? Well, that's still as simple as what it says on the tin—these are ideal containers to ship gallons (or other bottles) of milk to and from stores.



What about supporting people? We can start with the crates themselves, which stack ingeniously using a slight "lip" at the bottom that slots into the crate below. This is incredibly smart design, but the lip is really shallow. That means it works fine when the crates are either fully empty (with no one walking on top of them!) or filled with heavy milk, but the combination of slightly rounded edges on both sides means that there's quite a bit of "give" in how the milk crates fit together.



The amount of give stacks with the crates, so while two crates might not wobble much, seven crates end up with a lot of give to sway back and forth—especially when they're sitting on an uneven surface, like grass. When someone attempts to walk across the highest milk crates in the stack, they're applying weight and a directional vector to only the topmost part of the stack, which easily causes the entire row to fall over like a Jenga tower.The climber is rolling a blunt at the same time, which really illustrates how calm and steady he stays—moving the rest of his body as little as possible. To mimic his method, consider carrying a full glass of water and trying not to spill it to retain your balance.

And whatever you do, just be careful. No one wants to cry over spilled milk.

SCIENTISTS JUST CREATED THE COLDEST TEMPERATURE EVER RECORDED IN THE LAB

SUSHIL MISHRA-
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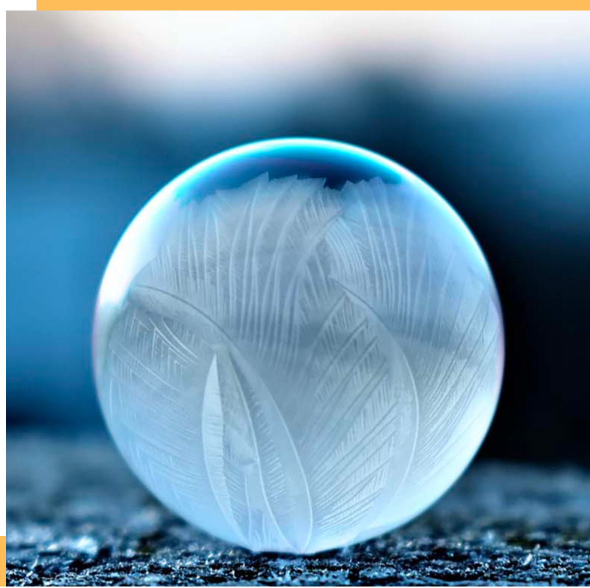


Researchers from four universities in Germany have created the coldest temperature ever recorded in a lab—38 trillionths of a degree warmer than absolute zero to be exact, according to their new work, recently published in the journal *Physical Review Letters*.

The bone-chilling temperature only persisted for a few seconds at the University of Bremen's Center for Applied Space Technology and Microgravity, but the breakthrough could have longstanding ramifications for our understanding of quantum mechanics.

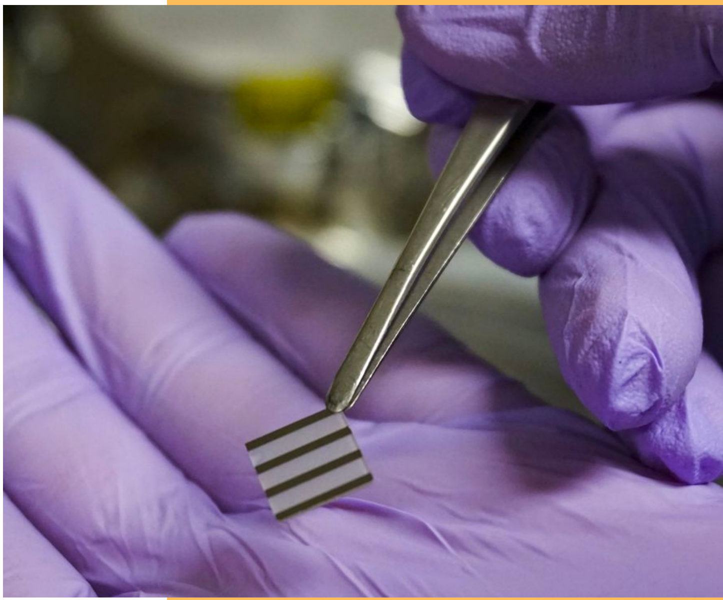
That's because the closer we get to absolute zero—the lowest possible temperature that we could ever theoretically reach, as outlined by the laws of thermodynamics—the more peculiarly particles, and therefore substances, act. Liquid helium, for instance, becomes a "superfluid" at significantly low temperatures, meaning that it flows without any resistance from friction. Nitrogen freezes at -210 degrees Celsius. At cool enough temperatures, some particles even take on wave-like characteristics.

Absolute zero is equal to -273.15 degrees Celsius, or -459.67 degrees Fahrenheit, but most commonly, it's measured as 0 Kelvins. This is the point at which "the fundamental particles of nature have minimal vibrational motion," according to ScienceDaily. However, it's impossible for scientists to create absolute zero conditions in the lab.The mechanism at play here is "a time-domain matter-wave lens system," according to the team's research paper. A matter wave is just what it sounds like: matter that is behaving like a wave. This is part of quantum physics, where everything we previously thought we knew gets a little wobbly upon close examination. In this case, scientists used an magnetic lens to shape a quantum gas, and used that to make a matter wave focus and behave in a particular way. A regular gas is made of a loose arrangement of discrete particles, but a quantum gas is no such predictable material. In this case, the quantum gas is a perplexing state of matter called a Bose-Einstein condensate.The researchers, from the University of Bremen, Leibniz University Hannover, the Humboldt University of Berlin, and the Johannes Gutenberg University Mainz, say they envision future researchers making the particles go even slower, with a top potential "weightlessness" period of up to 17 seconds.

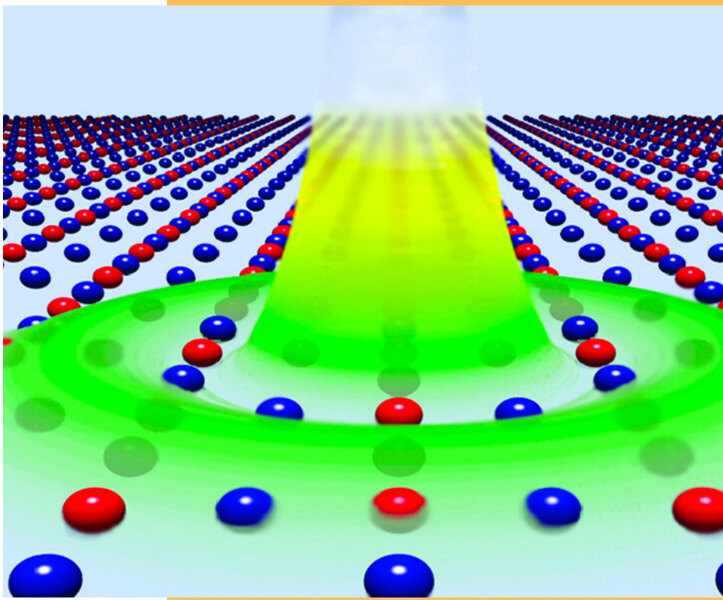
TEACHING QUANTUM MATERIALS HOW TO REMEMBER

SWAPNIL RAUT
FACULTY

The biological learning methods of habituation and sensitization help organisms, including humans, adapt to changes in their environment. Each can be exemplified by riding a bike. As you learn to ride, you become habituated to the bike's wobbles and respond less to its tilts and vibrations. You're able to ride faster and farther as a result. But if you fall and hurt yourself, you'll be more sensitized to the bike's instability, and as a result more dependent on the brakes or training tools.

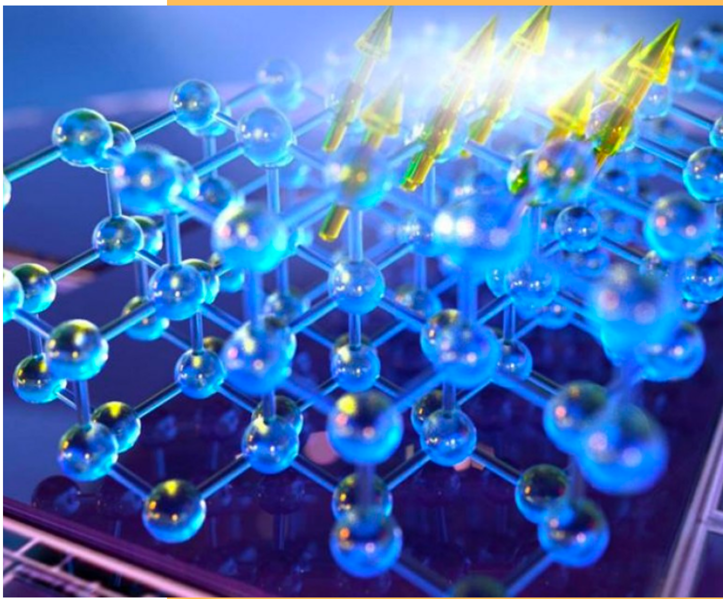


Scientists in the field of neuromorphic computing, which aims to make computers smarter and more independent from human input, are working to reproduce aspects of habituation and sensitization in hardware. A new paper in *Proceedings of the National Academy of Sciences* demonstrates similar behaviours in a semiconductor called nickel oxide, which could help researchers develop more agile and adaptable devices.



In living organisms, habituation and sensitization can help resolve the stability-plasticity dilemma, whether we decide to hold onto old information (be more stable), or be more responsive to new information (be more plastic). Just as neither the overly cautious cyclist who never gains speed nor the reckless cyclist who never brakes will master the art of riding, machines won't learn effectively if they can't determine how to prioritize items within massive amounts of data or information.

But for a computer to learn how to learn better, it must be fundamentally different from modern machines. "The traditional materials used for electronics have not been designed for brain-inspired computing," says Shriram Ramanathan, PhD, a professor at Purdue University and one of the study's authors. Consumer products will require greater advancement in the neuromorphic computing field than this sole study, however. Here, habituation and sensitization appeared as chemical reactions to hydrogen and ozone, but computers run on an electric current rather than hydrogen or ozone gas. "Being able to do all of this by electrical stimulus will be fascinating," Ramanathan says. "Then you can start to use traditional stimulus that is historically used in electronics."



ELON MUSK HAS BIG PLANS FOR TURNING THIS GREENHOUSE GAS INTO ROCKET FUEL

SAISH S
STUDENT

Noted billionaire space meddler and Twitter raconteur Elon Musk announced earlier this month that SpaceX will begin making rocket fuel out of carbon dioxide (CO_2), a colourless gas that accounts for up to 80 per cent of Earth's greenhouse gas emissions, according to 2019 data from the U.S. Environmental Protection Agency.

Given that the atmosphere on Mars is made up of 95 per cent carbon dioxide, it's likely that Musk has taken on this venture to prepare for the long return journey from Mars. But the process could also be good news for Earth if we could use up (or blast out) some of the planet's excess CO_2.

New York startup Air Company is already in the business of converting Earth's CO_2 into usable products in a carbon-neutral process, so the concept has some precedent. *Popular Mechanics* spoke to the company to learn more about how it works.

"Right now, the hydrocarbons that make up both RP-1 [a rocket fuel blend] and methane in rocket fuel come from fossil fuels in the ground," explains Stafford Sheehan, co-founder and chief technology officer at Air Company. "We make those hydrocarbons using CO_2 from the air instead. Our CO_2 supply is presently biogenic, as it is captured as the byproduct of industrial alcohol plants; however, we can use CO_2 from anywhere, including direct air capture."

Once there's a source of carbon dioxide, the secret is to electrify it in order to re-bond its molecules. "CO_2, being at the bottom of the energy ladder, cannot be used as a fuel," says Di-Jia Liu, a senior chemist at Lemont, Illinois-based Argonne National Laboratory. "Through electrocatalysis or catalysis with water, however, CO_2 can be converted into hydrocarbons, such as ethanol or kerosene, by combining the carbon atoms in CO_2 and the hydrogen atoms in water."

"This concept is not from 'thin air' (no pun intended), but built upon recent progress in this technology," Liu explains. He also points out that the technology could allow space travelers in transit to recycle their own CO_2 in realtime on long journeys.

"Space travel from Earth to Mars takes about seven months," he says. "For a human mission, imagine how much CO_2 will be produced along the way."