## ***The common background of ice cream, the Mpemba effect, and Schrödinger's cat***

***The bizarre circumstances AI enthusiasts face when stepping into quantum mechanics, dreaming of their ultimate tool, a super machine.***

Quite some years ago, a popular quiz show on one of the main German television channels entitled 'Who on earth knows something like that?' (Wer weiß denn so was?) entertained the viewers with somewhat absurd questions similar to the one above. Participants were asked to select from a row of answers the ones that related to obscure topics.

Here, AI enthusiasts might presume what the topic of interest is in remembering the cat in the box, at the same time, alive and dead. With this example, 1935 (BE 2478), the Austrian physicist Erwin Schrödinger hinted at the difficulties of imagining 'quantum mechanics' in the real world (1, 2). The hype around AI brought quantum mechanics to the forefront as a means of developing a machine with incredible speed, driving AI closer to changing humanity as we know it today (3).

<u>The gratifying story</u>

Yet ice cream hardly has anything to do with quantum mechanics, and no one expects the Mpemba effect to be known outside those in physics, let alone the general public. However, the story behind the effect is noteworthy, demonstrating how clever curiosity detects a hidden natural law. A 13-year-old pupil of a Secondary School in Tanzania, East Africa, 1963 (BE 2506), hurried to push his preparation for an ice cream, still quite hot, into the refrigerator, while his buddies did so only after their preparation had cooled down. (He wanted to find a place for his ice cream before the others occupied every available space in the fridge.) To his amazement, his ice cream froze before the ice creams of his friends.

He started a more 'controlled experiment' with water at home, observing the same phenomenon. His teachers were not very interested in his question, why hot water froze faster than cold one. Erastro Mpemba didn't forget his observation and took the opportunity to talk about it to a physicist visiting his school from the university in the capital. Denis Osborn, an English professor working in Africa to support science there, was open to the question of Mpemba in following up on the phenomenon in the laboratory. In 1969 (BE 2512), he published the finding 'that hot liquids froze faster than cold ones' in placing Mpemba as the first author, by rightly stating that 'no question should be ridiculed' (4, 5).

<u>The Mpemba effect</u>

It is somewhat curious that the phenomenon came to the attention in earnest in a tropical country. That is, because water pipes in so-called ‘moderate climate’, where temperatures might drop to zero or even down to -20 $C^0$, plumbers know that water pipes, in freezing winter climate, carrying warm water, burst earlier than those with cold water. It is also said that the ancient Greek philosopher Aristotle and the philosopher of the early Age of Enlightenment, Descartes (‘I think, so I am’), observed that hot water cools faster than that which is not as hot (6).

Another twist in the Mbemba story is that he observed the phenomenon with a mixture of ingredients he thought would freeze into a tasty ice cream. It is not mentioned what he used, but most probably not only water, but also milk and sugar. The experiments with water, as published by Osborn, could not easily be repeated by others and are still controversially discussed. Water is difficult to study because freezing depends on various factors, such as dissolved gases, the surface of the container, and the location within the container at which measurements of the temperature are taken (6).

## Mpemba throughout all areas of physics

But in materials not well known, such as polylactide crystallization or in magnetoresistance manganites, the Mbemba effect was clearly visible. Polylactide acids are some biodegradable plastics that can be transformed through crystallization into different heat-resistant and stable materials. The crystallization process demonstrates the Mpemba effect (7). The magnetoresistive manganites are a class of ceramics that change electrical resistance in a magnetic field. While exposed to different temperatures, the resistance to the electric field changes, showing the Mbemba effect as well (8). Further investigation into a number of completely different systems could be concluded in stating that ‘when a system is pushed further from equilibrium can find a quicker path back to a steady state.’ That can be both ways, either from low to high or, as explained here, from high to low (5, 9).

## The challenge of classical mechanics

So far, the Mpemba effect fits into systems that follow the theory based on Isaac Newton's definition of ‘classical mechanics.’ While Newton still explained it in a way an educated layman could understand, mathematicians were soon around putting everything in mathematical formulas through which mechanics could be explained for all areas of physics, from fluids, gases, macromolecules, and finally, stars, planets, and galaxies, which are forced by any sort of energy to move along. By explaining gravidity as ‘spacetime,’ Einstein’s theory of relativity also found its place (10). All was sunshine and rainbows for about two hundred years, until Werner Heisenberg came up with the quantum theory in 1925 (2468), but the need for a revised theory of mechanics had already been sensed by Max Planck and Albert Einstein at the beginning of the $20^{th}$ century (11).

## The light behind the quantum theory

It was light and electricity, and the findings of the German scientist, Heinrich Hertz, who detected the photoelectric effect in 1887 (BE 2430), which were behind the attempt to come up with the quantum theory. (Think about him when plastering the roof of your house with solar panels.) Light and electricity are thought initially to appear in waves. Hertz noticed that ultraviolet light shining on a metal plate produced a spark (signal), indicating that ultraviolet light caused an electric effect. Later, other scientists found that wavelengths, such as red, did not have the same effect. In 1905 (BE 2448), Einstein concluded that below a certain frequency of light, no electrons were emitted from the metal panel. Ultraviolet did, and red didn't. That means the wave's frequency explained the effect, not whether the light was bright or not so bright. The light emitted photons, and electrons were subsequently emitted from the metal panel. The importance of light lies in its different colors, which stand for different wavelengths. Photons are particles, quantal, and are emitted in waves. Electrons of the photons of red color vanish, while those from ultraviolet light, after hitting the metal are releasing its energy as electricity. This is because the energy of the photons of the different colors of light is different. In 1924 (BE 2467), the French scientist de Broglie concluded that light and all matter exhibit both wave-like and particle-like behavior (12).

<u>After a hundred years, quantum mechanics still a mystery even for physicists</u>

The one-hundred-year anniversary of the theory was not greeted with a uniform enthusiasm by the scientific world, as judged by the statement by one author in the science magazine Nature, writing 'that 'a century on, physics still can't agree what our most fundamental picture of reality tells us' (11). The main problem is that at a particular time, a particular particle can be measured, but its positions before and after that time are unknown. The scientist Bohr, one of the most significant inventors behind the theory, suggested a measurement of the 'position of momentum' of an electron or particle, to be the square of the wavefunction. He admitted that we can never precisely predict the outcome of a quantum measurement. A given wave function of one particle also relates to all of the particles of that wave. The problem is called entanglement. Related particles can be anywhere close to or somewhere far away in the cosmos.

<u>The Copenhagen interpretation</u>

Learning about this in school, you might have difficulties understanding it. Suppose the teacher lowers your grade in physics to 'not passed,' you can object, indicating that even Einstein didn't agree with the theory. You might even cite the EPR article he published with Boris Podelsky and Nathan Rosen in 1935 (BE 2478). The teacher might retaliate that Einstein, of course, understood the theory but found it incomplete, mainly because of the entanglement controversy. His phrase 'God doesn't play dice with the universe' went into history. Well, if such an encounter between teacher and student had actually happened, the student must have been one of the best in the whole school, since within one hundred years the difference between Einstein and Schröder on one side and Heisenberg and Bohr, the Danish physicist, on the other site remains. The latter two worked together in the institute of Bohr in the Danish capital in the twentieth years of last century, and their standpoint is known as the Copenhagen interpretation. When teaching and discussing quantum theory nowadays, the issues introduced will be presented on the basis of 'quantum Bayesianism (QBism)' (11).

<u>A quarrel called 'QBism'</u>

The Bayesian 'compromise' (of not knowing or not accepting what is true) is known in statistics. It is used when a probability within the beliefs of a wide range of individuals leans toward a particular side of a hypothesis, supported by a set of data. It is crucial that the belief be continuously tested against new data, with the probability still pointing in the same direction (13). Quantum Bayesianism (QBism) uses a somewhat different trick, turning towards classical physics, which has missed the chance to question its own tools. In realizing that there is numerous evidence that quantum mechanics theory is working, but those behind classical physics never questioned whether the wavefunction is real. The non-locality of the quantum is wrongly mystified through the belief that, when something happens, one must go to interrogate who was around (when it happened). Likewise, the 'Now' (as emphasized particularly by Einstein, who did not fully agree with the quantum theory) was never missing from the physical description. Space-time is a four-dimensional mathematical construct. In reality, we live through time and also in space (14). Arguing in favor of the quantum theory on the basis of QBism, you might be accused of being unscientific or an illusionist.

<u>Remaining problems counter a 'wave' of encouraging evidence for quantum mechanics</u>

The widely accepted problem with quantum mechanics is that we expect the rules for low-energy systems to also apply to high-energy processes. For instance, looking at the mass of the Higgs particle or the energy density of the vacuum, the values that come up don't fit together at high energy. Further, it wasn't yet possible to formulate a quantum theory for gravity and curved spacetime (11).

Presently, it seems that the scientific literature reveals evidence for the reality of quantum mechanics almost in short intervals. There are noninvasive medical tests that allow one to observe images of organs and soft tissue on the computer. While trying to enhance magnetic resonance imaging (MRI) by injecting designer molecules, the images improved tremendously, giving the impression that it was actually similar to a unprecise quantum computer (15). Another recent news presented evidence for the wave and particle postulation in quantum mechanics. Assembling 7.000 atoms of sodium metal, about 8 nanometers wide, into a superposition of different locations 133 nanometers apart did not behave like a billiard ball moving through the experimental setup, instead resembled a wave and formed a detectable pattern (16). Another experiment used hot microscopic glass beads that dropped into water onto an irregularly shaped bottom. The hotter one assembled at the bottom earlier than the cooler one (17).

## The usefulness of the Mpemba effect in quantum computers

The Mpemba effect also works on the subatomic level (5). When particles are far away from equilibrium, they find various paths back to the target, in surprising shortcuts (18). Directly linked to the quantum technique, two different systems with the Mpemba effect were published in 2024 (BE 2567). As far as the layman understands, in present experimental quantum computer trials, certain charged ions, called qubits (quantum bits), could be fixed as oscillating XY spins in entanglement, via laser beams and electromagnetic fields in a vacuum. Within an experimental quantum computer trial, a Strontium-88 qubit reacts as a hot qubit faster than in a colder system. The reverse arrangement also showed the Mbemba effect (19). One of the main tasks within the trials seems to be keeping the entanglement in a working condition, so entanglement asymmetry in the XY spin is a problem. The Mpemba effect under these conditions meant that the larger the asymmetry, the easier it was for a broken symmetry to be preserved (20).

## The High-resources theory in the real world

The examples listed here show that the Mpemba effect operates across the full range of systems in an extraordinary state of 'high resources' and decreases in states of lower or zero resources. From a very high temperature to a low temperature, even to a temperature close to absolute zero. Within the 'resource theory' system, this will be referred to as 'Athermality'. Comparable systems are 'Non-stationary', 'Asymmetry', and Quantum coherence. The latter points to quantum particles remaining in a stable, synchronized relationship with one another (9). It is important to keep in mind that the Mpember effect also works the other way round.

The effect has the potential to be useful in the real world, i.e., in the development of the quantum computer. Given that the nuclear spin of atoms will be the core effect in the quantum computer operating on the data material, this is presently achieved in a vacuum and at or near absolute zero ($0^K$ or -273.15 °C) (21). The nuclear spins of atoms could recently be stabilized within a cool quantum computing ship by a drop in temperature of 10% using the liquefied gas chloroform (Zawadzki, K. (unpublished, mentioned in (5)).

## Outlook

A readable, informative introduction for laypeople about the development and structure of quantum computers, which resemble highly complex, massive refrigerators, was recently outlined in the magazine Science (21). One of the required ingredients is helium-3, which lacks one neutron relative to helium-4. The gas helium in what we breathe occupies 0.0001% of the volume. Formerly, the gas was used to fill birthday balloons, but now it is a byproduct of components used in producing atomic weapons and is extremely expensive.

Experience with the law of economics tells us that the more atomic weapons are produced, the more affordable supercomputers based on quantum mechanics will be. Drawing a line with Murphy's law* from being afraid of the devastating effects of atomic weapons on human society and the danger that reborn Hitler and Stalin will finally use AI and supercomputers to establish their power to enslave mankind could be worrisome. To appease your mental disturbances with ice cream might help. In Thailand, it is very tasty, and probably in Tanzania by now as well.

*' Whatever can go wrong will go wrong at the most unfavorable time.' There are enjoyable books for kids, teens, and adults on the market that elaborate on this through everyday experiences.

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Frank P. Schelp is responsible for the manuscript's content, and the points of view expressed might not reflect the stance and policy of the Faculty of Public Health, Khon Kaen University, Thailand.

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Grammarly software was used to improve English. The software is hardly recommended, since it changes the meaning in a different, undesired direction. The program was not yet deleted from the ‘Word’ files due to a better alternative. The AI version was considered only after writing the text originally and was accepted as seldom as possible when the English expression seemed to be more comprehensible.