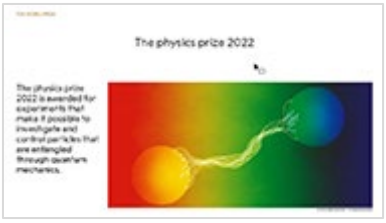
THE NOBEL PRIZE

Speaker's manuscript – Physics prize 2022
Research on quantum mechanics

The Nobel Prize in Physics

- The Nobel Prize in Physics is one of the five prizes founded by Alfred Nobel and awarded on 10 December every year.
- Before Alfred Nobel died on 10 December, 1896, he wrote in his will that the largest part of his fortune should be placed in a fund. The yearly interest on this fund would pay for a prize given to "those who, during the preceding year, shall have conferred the greatest benefit to humankind."
- The interest would be divided into five equal parts, with one part awarded to those who "shall have made the most important discovery or invention within the field of physics".
- This prize rewards important discoveries or inventions in the field of physics.

The 2022 physics prize



- The physics prize 2022 is awarded for experiments that make it possible to investigate and control particles that are entangled through quantum mechanics.
- It's about particles that are far apart and yet still connected, or entangled, with each other. That effect is a little "spooky," according to Albert Einstein.

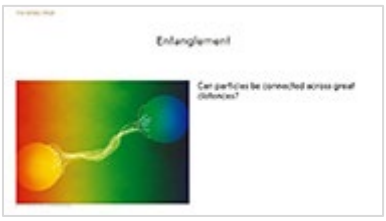
The 2022 physics laureates

- The 2022 Nobel Prize laureates in physics have developed experiments with particles of light, or photons, that are entangled. These experiments have confirmed the theory of quantum mechanics is correct and paved the way for a new quantum technology.
- The laureates were all born in the 1940s, but in different countries: the United States, France and Austria. They have not worked together, but rather as part of different research teams.

Quantum mechanics

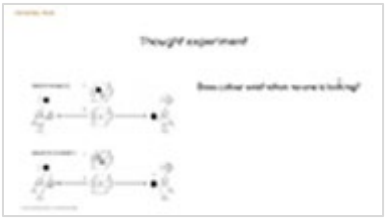
- Quantum mechanics was developed about a hundred years ago. It brought about a revolution in how we view the underlying forces that make up our world. For example, chance plays a decisive role in the description of the small particles and packets of light that are the basic building blocks of the world. Conventional physics' description of the world as essentially completely predictable just doesn't hold true on this fundamental level.
- Physicists came to different conclusions about what this means. For example, Niels Bohr and Albert Einstein, who were awarded the physics prize in 1922 and 1921 respectively, disagreed on this matter. Bohr was more convinced of quantum mechanics' validity than Einstein, who objected to the fundamental role assigned to chance in the theory of quantum mechanics.

Entanglement



- One of the consequences of quantum mechanics is that systems of particles can be divided into separate groups that are still entangled and must be described as one unit. That means that if someone measures an attribute of one of a pair of entangled particles, they can be certain what the result of measuring the other would be.
- The state of one particle depends in some way on the state of the other, even though they are separated by a long distance and even though no signals are sent between them. This is possible due to the underlying premise of quantum mechanics that the state or attribute of each particle is not predetermined before the measurement is taken. Only when the measurement is taken is the state of the measured particle determined, and immediately also the other particle's state.
- This conflicts with our common understanding of cause and effect and how the world works. Albert Einstein thought entanglement was a sign that quantum mechanics gave an incomplete description and needed to be supplemented. Could it be that there are some unknown attributes - hidden variables - that can give us an explanation without the uncertainty and chance of quantum mechanics?

Thought experiment



- Quantum mechanics' entangled pairs can be compared to a machine that throws out balls of opposite colours in opposite directions. When Bob catches a ball and sees that it is black, he knows immediately that Alice has caught a white one. In a theory that uses hidden variables, the balls must contain information right from the start about what colour they will be. But quantum mechanics says that the balls are grey until the moment someone looks at them, when one randomly turns white and the other black.

Real experiments

- Is there a way we could determine whether quantum mechanics is correct or there are some hidden variables? Yes: physicist John Bell (1928–1990) discovered that there is a type of experiment that can determine whether the world is purely quantum mechanical, or whether there could be another description with hidden variables.
- The 2022 Nobel Prize laureates in physics have developed just such experiments. John F. Clauser created entangled pairs of photons in one experiment by shining special kinds of light at calcium atoms. He was then able to take measurements of the photons that demonstrated that quantum mechanics is correct and that there are no hidden variables. At left in the picture we see Alain Aspect, who developed this experiment further and achieved even clearer and more definitive results. Anton Zeilinger later conducted other experiments in which he created entangled pairs of photons by shining a laser at a special crystal. He was also able to transfer the entanglement of two particles to two other particles that had never been in contact with each other.

Quantum technology

- Are there any practical uses for quantum mechanical entanglement? We are entering a new era of possibilities for storing, transferring and manipulating information. Some applications:
    - Secure storage and transfer of information through quantum encryption.
    - Transfer of quantum information across great distances through optical fibre cables.
    - Fast and efficient quantum computers.

“I was having fun. It was a challenging experiment. I thought it was important at the time, even though everybody told me I was crazy and was going to ruin my career by doing it.”

- The quotation comes from a telephone interview John F. Clauser gave in conjunction with the announcement of the 2022 Nobel Prize in Physics. In the interview, he talks about his research and about the reactions he got when he proposed the idea of testing John Bell’s theories in a laboratory setting.
- The photo shows Clauser at a boat club. He enjoys sailboat racing in his free time.