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THE ROYAL SWEDISH ACADEMY OF SCIENCES

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2025 to **John Clarke**, **Michel H. Devoret** and **John M. Martinis** "for the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit".

The Nobel Prize 2025 **in Physics**

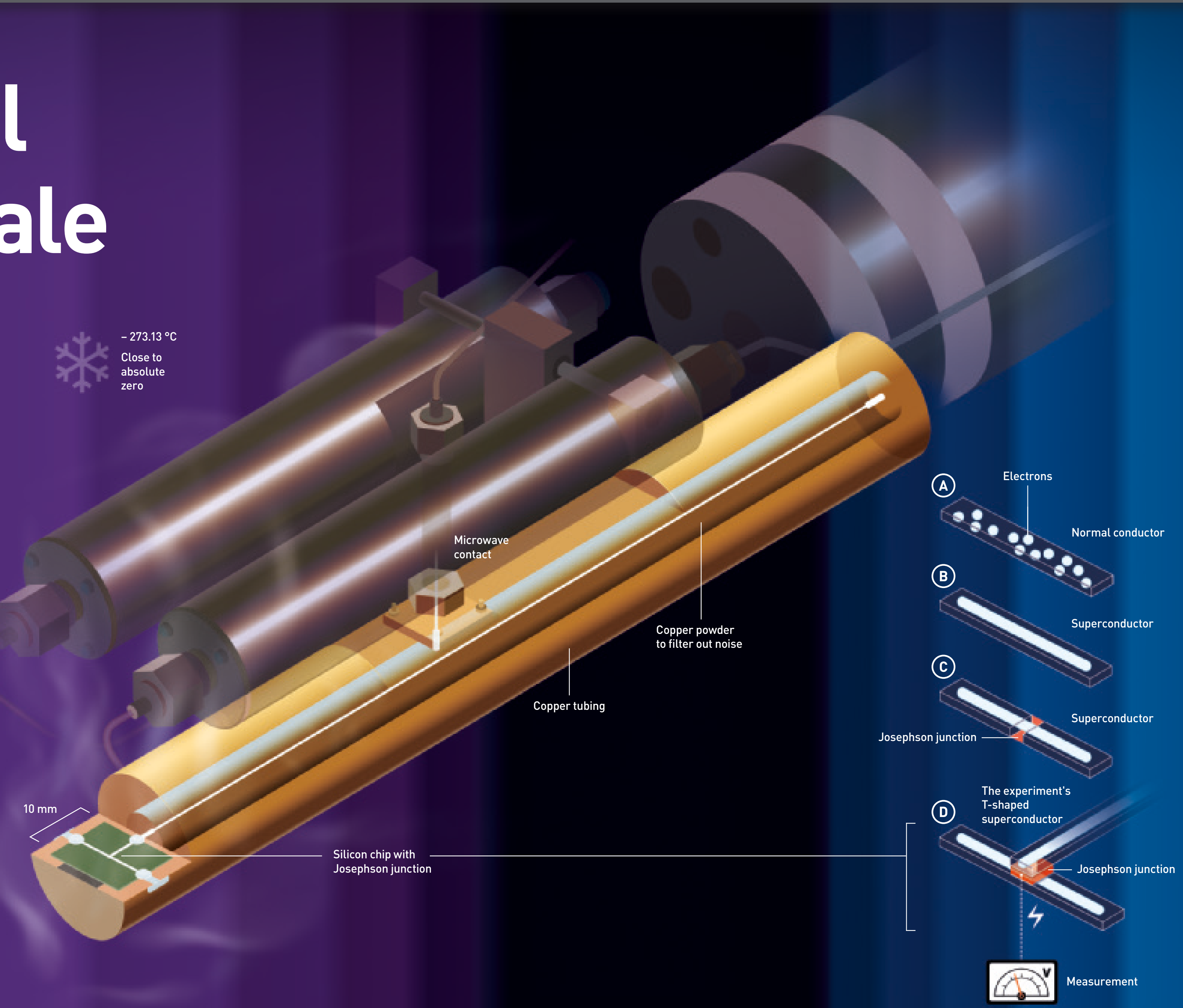
Quantum mechanical effects on a large scale

Quantum mechanics describes the world of elementary particles. This year's laureates, John Clarke, Michel H. Devoret and John M. Martinis, demonstrated that quantum mechanics can also be important in larger formats. They created a type of artificial atom in a superconducting electrical circuit with billions of particles. Managing quantum mechanical effects in a macroscopic system is valuable, both for basic research and for the development of new quantum technology.

Physicists often describe phenomena that involve individual particles as microscopic, although they are far smaller than anything that can be seen in an optical microscope. In contrast, there are also *macroscopic* phenomena, which involve large numbers of particles. The laureates' experiment demonstrates how a macroscopic system can have quantum properties, just like single particles can.

In their experiment, the laureates showed that they could control and investigate a state in which all the charged particles in the electrical circuit behave as if they were a single particle, one that fills the entire circuit.

This particle-like system is trapped in a state in which current flows without any voltage – a state from which it does not have enough energy to escape. In the experiment, the system shows its quantum character by managing to escape the zero-voltage state by tunnelling, generating an electrical voltage. The laureates were also able to show that the system is quantised, which means it only absorbs or emits energy in specific amounts.



The experiment

A | In a normal electrical conductor, electrons jostle with each other and with the material, which creates electrical resistance.

B | In a superconductor, the electrons can behave in unison, as if they were a single particle that fills the entire electrical circuit. Quantum mechanics describes this state using a joint wave function.

C | The laureates used a component called a Josephson junction, in which two superconductors are separated by an insulating material. The wave function stretches across the gap, but the two sides interact in a special way. This is the state, involving billions of electrons, that represents tunnelling in the experiment.

D | The Josephson junction in the experiment forms a T-junction. The wave function can exist in a state in which current flows without voltage, and in another state where there is a voltage. The wave function is trapped behind a type of energy barrier. When a voltage is measured, the wave function has tunnelled through the barrier.

Microwaves

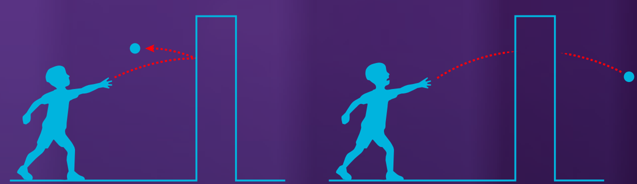
The laureates fed energy into the experiment in the form of microwaves. They could then show that the state in which current flows without any voltage has fixed energy levels, just as in an atom.

The energy in microscopic processes is divided into separate packages, quanta, which is how quantum mechanics got its name. Here, quantisation is displayed in a macroscopic system.

John Clarke
Born 1942 in Cambridge, UK. Professor at University of California, Berkeley, USA.

Michel H. Devoret
Born 1953 in Paris, France. Professor at Yale University and University of California, Santa Barbara, USA.

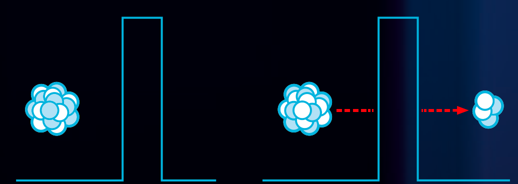
John M. Martinis
Born 1958 in Los Angeles, USA. Professor at University of California, Santa Barbara and Chief Technology Officer at Qolab, USA.



Tunnelling

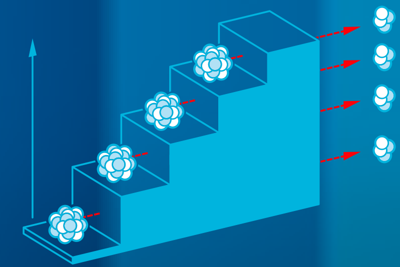
A ball consists of an astronomical number of particles. If you throw a ball at a wall, you can be sure it will bounce back every time.

You would be extremely surprised if the ball suddenly appeared on the other side of the wall. In quantum mechanics, that is called tunnelling and is exactly the type of phenomenon that has given quantum mechanics a reputation for being bizarre.



Tunnelling in atoms

For almost a century, physicists have known that tunnelling is necessary for a type of nuclear decay (alpha decay). A tiny piece of the atom's nucleus splits off and appears outside the nucleus, despite the presence of forces that form a barrier and enclose the nucleus's tiny particles.



Quantisation

A quantum mechanical system behind a barrier can have varying amounts of energy, but it can only absorb or emit specific amounts of this energy. The system is quantised. Tunnelling occurs more easily at a higher energy level than at a lower one.

Photo: Portrait of John Clarke: Brandon Sanchez; portrait of Michel H. Devoret: Peter Badge/Typos1; portrait of John M. Martinis: Liubov Lukashenko/Courtesy of Qolab

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More information about the Nobel Prize in Physics 2025 is available at *www.kva.se/nobelphysics2025* and *www.nobelprize.org*, with video and detailed information about the prize and the laureates.

Editors: Ulf Danielsson, Göran Johansson and Eva Lindroth, the Nobel Committee for Physics, Royal Swedish Academy of Sciences; Anna Davour, science writer; Clare Barnes, translator and Sara Rylander, editor, Royal Swedish Academy of Sciences. **Graphic design:** Studio Laufer **Illustrations:** Johan Jarnestad/Infographics.se **Print:** Åtta45

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