# Nobel Prize in physics awarded for discoveries about condensed states of matter

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**8 October 2016**

The 2016 Nobel Prize in Physics was awarded on October 4 to David Thouless, F. Duncan Haldane and J. Michael Kosterlitz for developing the mathematics to explain states of matter such as superconductors, superfluids and magnetic films. These discoveries have brought about a myriad of breakthroughs in our understanding of the ways and shapes matter can form and has laid the basis for whole new fields of technology.

This year's prize highlights the field of condensed matter physics, the study of atoms as they interact in very extreme states such as temperatures near absolute zero. It also includes understanding the behavior of magnetism, crystal structures and fluids both as disparate and combined effects. The field has had immense impact on culture: one part of it alone, the understanding of the flow of electrons in metals of various types, has produced the transistor, the integrated circuit, the light-emitting diode, and the solar cell.

Electronics devices themselves have been refined through this field of physics. The type of magnetic reader used in today's hard drives is a direct result of the study of condensed matter. This has greatly reduced the size and cost of memory storage, allowing for the mass production of personal computers.

Other benefits of the study of condensed matter include a deeper understanding of quantum mechanics, a realm which is hard to directly probe as a result of random atomic movements. However, when matter is cooled to just above -273 degrees Celsius (absolute zero), properties normally only seen in the quantum world suddenly manifest on a macroscopic scale.

Studies in what would become known as condensed matter began in the early 19th century, as scientists began to characterize different properties of metals—such as luster, ductility and electrical conductivity—and to attempt to liquefy all sorts of gases, such as hydrogen and nitrogen. One of the more practical results of this research was the realization that beyond certain temperatures and pressure, gases and liquids become indistinguishable. These so-called "superfluids" are what spin turbines to make electricity in coal and nuclear power plants.

The capstone of a century's work occurred in 1911, when mercury was cooled to a point where it suddenly had no electrical resistance. Current could flow through this newly found "superconductor" without any loss of energy, persisting without an external power source. While this was certainly not the last of the new discoveries, it prompted a qualitative shift in the physics needed to understand what was going on. New states of matter could no longer be described by classical mechanics, which had guided all previous studies, but had to be understood with the newly emerging quantum mechanics and the mathematics that describe symmetries in physical systems.

Symmetries in physics were first worked out by mathematician Emmy Noether in 1915. These bear a certain relation to symmetries found in geometric shapes but have the added benefit of providing a stable quantity that can be observed experimentally. For example, the mass of an object (the amount of matter contained within that object's volume) does not change whether it on is Earth or if it travels to Mars.

Such symmetries have been used in analysis of condensed matter to explain why materials become superconductive at low temperatures as well as why materials suddenly become magnetic when cooled. Both relate to the orientation—the symmetry—between atoms when transitioning from high to low temperatures.

The research done by Thouless, Haldane and Kosterlitz focuses on symmetries that occur in the structure of matter when it changes temperature. For example, the crystalline structure of ice is more symmetric than liquid water, a change in the phase of water induced by reducing the temperature below 0 degrees Celsius.

Instead of studying water, however, the three scientists were interested in overcoming a theorized instability when matter is made flat enough to be considered two-dimensional and/or thin enough to be considered one-dimensional. Previous studies hypothesized that the constant motion of particles at the atomic level, even when chilled to just above absolute zero, would destroy any sort of cohesion between the atoms, making two-dimensional forms of matter impossible to create.

Thouless challenged this idea by using topology, the geometry that, for example, describes the similarities between a sphere and a bowl and the differences between a sphere and a donut—a sphere and bowl have no holes while a donut has one hole. He found that it was possible to deform matter through these geometric symmetries to create stable two-dimensional structures. Haldane and Kosterlitz extended these ideas to deeper connections between the mathematical classification of physical surfaces, including making stable one-dimensional structures.

More importantly in a practical sense, the union of condensed matter analysis and topology provided the description for the transitions to and from various states of one-, two- and three-dimensional states of matter. As such, the various properties of the structures could be theoretically predicted and tested experimentally. As the sensitivity of technology needed to test these materials has increased, the predictions are more and more being borne out, with even more esoteric yet useful characteristics being discovered.

Such results point to a whole new field of “topological” materials including insulators, supercounductors and metals. These are merely examples of areas which, over the past decade, have been on the frontlines of research in condensed matter physics. Contained therein is the combined promise of new generations of electronic devices, superconductors and possible quantum computers, alongside a deeper and more comprehensive understanding of the interactions of matter in wholly new forms.