



Mathematical Approaches to Cutting-Edge Problems in Physics

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Seminar before the award of Nobel prize in physiology or medicine



There are 111 Nobel prizes awarded in physics to date (not including the 2018 Nobel Prize, which is to be awarded right after this seminar).

A total of 207 scientists have been awarded Nobel prizes in physics to date.

2 women have been awarded Nobel prizes in physics to date.

Nobel prize in physics is announced every year on the first Tuesday of October at 1145h CEST (Central European Summer Time — Swedish Local Time), which corresponds to 1445h PKT (Pakistan Standard Time), live streamed at <https://www.nobelprize.org>

Nobel prize in physics is awarded ([live streamed](#)) in the Stockholm Concert Hall on October 10 (this year at 1630 CET → 2030 PKT) — the anniversary of Alfred Nobel

What are the qualities you need to win a Nobel prize in physics?

Physics was the discipline, which Alfred Nobel talked about first in his will from 1895. Toward the later part of the nineteenth century, physics was considered as the foremost of the sciences. Nobel's own research was, also, closely related to physics. Nobel prizes have been awarded both in the theoretical and the experimental physics. A deep knowledge and an [understanding of the physics as well as the mathematics behind the physical phenomenon](#) should end up in making notable contributions through [creative thinking and critical analysis](#). Of course, this means that the training of a physicist should start from [concept building and end up in problem solving \(in the classroom, in the laboratory, in the industry\)](#). The bold approach of [Paul Adrien Maurice Dirac](#) of not discarding the negative energy eigenvalues in the Dirac Hamiltonian as unphysical and interpreting them to represent positron brought Dirac, the 1933 Nobel prize in physics, for the theoretical prediction of positron, and [Carl David Anderson](#), the 1936 Nobel prize in physics, for the experimental discovery of positron. [Albert Einstein](#) could not visualize the expansion of universe through his cosmological equation and ended up missing the important discovery, which in his own words was “the greatest blunder of my life”. Another example of mathematics introducing new physics is the discovery of omega meson by Abdus Salam by looking at the empty space in the group structure. Examples of physics introducing new mathematics are, also, not uncommon. The examples are introduction of bosi numbers (which anti-commute) in the formulation of supersymmetry theory in an attempt to unify all forces of nature as well as definition of [determinant of a general tensor](#), when the speaker was working on [faster-than-light particles](#). Many times, simplicity of ideas takes over elegance in mathematics. The initial formulation of special theory of relativity was not mathematically elegant, but based on simple ideas. It was Herman Minkowski, who introduced [the four-dimensional-spacetime-vector-field formulation](#), which brought elegance to relativity theory by putting the equations in covariant form. The same goes with Glashow-Weinberg-Salam theory, which is based on simple ideas, but still needs mathematical elegance to be introduced by a mathematician. The knowledge based-economy converts cutting-edge physics problems into technology, bringing revenue to the nation (example, United States). However, one, often, fails to realize that [mathematics is the starting point of this journey to technology, a bridge through physics and engineering](#). Many of the results in physics have a basis in mathematics, *e. g.*, continuity of the wave function in quantum mechanics (a discontinuity would imply momentum becoming infinite, corresponding to infinite force) as well as continuity of the first derivative of the wave function (a discontinuity would imply energy becoming infinite). These conditions help determine the arbitrary constants appearing in the wave function. The approach of a mathematician and a physicist to various physical formulae and concepts would be completely different. Take the example of two conservative forces:

$$\text{Electrostatic Force} = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2} \bullet \text{Gravitational Force} = \frac{Gm_1m_2}{r^2}$$

The physicist realizes that electrostatic force is strong (coupling constant 1/137), whereas gravitational force is weak (coupling constant of the order of 10^{-39}). The mathematician realizes that both are inverse square, central and conservative forces by focusing on $1/r^2$ dependence of both forces. Hence, if the expression of electrical potential is derived once, no need to do that for the gravitational force again, just replace $1/\epsilon_0$ with $4\pi G$, electrical charges with masses. Same goes with expressions of gravitational field inside and outside of a spherical mass distribution from similar expressions for the electrostatic field as well as [Gauss' law](#) for gravitation. Even the concept of conservative forces is looked differently by a physicist and a mathematician. A physicist recognizes the conservative force as the one in which, the work done upon traversing a closed path by a (electrically-, gravitationally-) charged particle is zero, whereas a mathematician just looks at the expression of force. If this expression just depends on the generalized coordinates (not velocities, not higher-order derivatives, not time) then it is a *conservative force*, otherwise a *dissipative force*. This lecture is dedicated to loving memory of [Abdus Salam](#), physics Nobel laureate from Pakistan. Professor Salam was very kind to the speaker, answered all his letters and sent message on the eve of 50 years of origin of quantum mechanics. The speaker had the honor to meet this legendary physicist in 1988 during his visit to the International Center for Theoretical Physics (now renamed as the Abdus Salam International Center for Theoretical Physics: [AS-ICTP](#)), a center established in 1964 due to his efforts. He was Founding Director of [SUPARCO](#) (Pakistan Space and Upper Atmosphere Research Commission), where the speaker worked during 1992-95. In addition, he established Theoretical Physics Group at PINSTECH. He was the supervisor of PhD dissertation of Ansaruddin Syed (external examiner of my [MSc thesis](#)), Chairman, [Department of Mathematics, Jinnah University for Women](#). Other notable doctoral students are Yuval Ne'eman, John Taylor, Riazuddin, Fayyazuddin and Ghulam Murtaza. Salam shared the 1979 [Nobel prize in physics](#) with [Sheldon Lee Glashow](#) and [Steven Weinberg](#), both hailing from [Harvard University](#), “for their contributions to the theory of unified weak and electromagnetic interaction between elementary particles, including inter alia, the prediction the weak neutral current” (exact citation from website of [the Nobel Prize](#)). Salam was born on January 29, 1926 in Jhang Maghiāna, British India (now in Pakistan). He obtained his MA in 1946 from Government College, Lahore (now [GC University](#)) affiliated at that time with [University of the Punjab](#). He was, subsequently, awarded a scholarship to study at [St. John's College, University of Cambridge](#), England, from where he obtained BA (Honors) with a double first in mathematics and physics in 1949. In 1951, he obtained his PhD in theoretical physics from [University of Cambridge](#). Salam returned to Government College in 1951 to teach mathematics and became Chairman of [Department of Mathematics, University of the Punjab](#). In 1954, he joined faculty of [University of Cambridge](#). In 1980, he [visited Department of Physics, University of Karachi](#). Salam passed away on November 21, 1996 in Oxford, England. Besides Nobel Prize, Salam was awarded Smith Prize (1950), Adams Prize (1958), Sitara-é-Pakistan (1959), Hughes Medal (1964), Atoms for Peace Prize (1968), Royal Medal (1978), Matteucci Medal (1978), John Torrence Tate Medal (1978), Nishan-é-Intiaz (1979), Einstein Medal (1979), Lomonosov Gold Medal (1983), Catalunya International Prize (1990) and Copley Medal (1990). He was elected Fellow of [the Royal Society](#) in 1959 and made Honorary Knight Commander of the Order of the British Empire in 1989. His major contributions are Pati-Salam model, Goldstone's theorem and magnetic photon. The life history of Abdus Salam teaches us a constant struggle both on the home front and abroad to advance physics research and establishment of various institutions in Pakistan and Italy to attain this goal. He was encouraging budding students from Pakistan to achieve their dreams. He donated his Nobel diploma to [GC University](#), never took a foreign citizenship and chose to be buried in Pakistan.

Keywords: Abdus Salam • Alfred Nobel • Nobel prize • Royal Swedish Academy of Sciences • **Related Links:** [Nobel minds 2018](#) • [Prize announcement 2018](#) • [Physics Nobel lectures 2018 AA GM DS](#) • [The Nobel prize award ceremony 2018](#)