Title: Nobel prize and Fundamental Physics Prize in 2022

Speaker: Prof. Apoorva Patel (PHY, IISc)

Abstract: This year, two highly coveted physics prizes in physics have been awarded to works related to quantum computing and information theory. In this talk, Prof. Apoorva gives theoretical and experimental insights into relevant research areas that lead to this monumental achievement. The central theme of the talk revolves around quantum superposition and entanglement. In the end, he also discusses the current challenges of this field as well as its impact on the coming future.

Nobel Prize Recipients: Alain Aspect, John Clauser and Anton Zellinger.

Citation: "for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science".

Historical background: In 1935, the **EPR** debate started with various responses from esteemed scientists. It also triggered certain philosophical questions like the meaning of reality (Realism) in physics and what is observable and what is not. The main concern was if there exists some hidden variable theory for quantum mechanics. John Bell (1964) derived **Bell's theorem**, which rules out local hidden variables. Quantum entanglement is the central theme of Bell inequalities.

Measurements on EPR pairs are correlated, and hence they are inseparable. Conservation laws in physics imply correlations. For example, if a particle breaks into two parts, then its momentum is correlated. Measuring the momentum of one of them is sufficient to predict the momentum of the other parts. Entanglement is another correlation existing in the quantum only.

Hidden variable theory do exists in classical realm. It has been successfully used in Brownian dynamics. We can successfully derive certain statistical properties of Brownian motion by an effective theory. We don't need much detail of all the collisions occurring at the atomic scale. John Bell showed that finding any such local hidden variable theory is violated by experiments.

Hence, Quantum mechanics is a non-local theory.

Alain Aspect showed that if two entangled photons moving in the opposite direction is measured by two detectors oriented at 22.5° maximally violate Bell inequality.

Clauser and his team experimentally tasted CHSH inequality (a version of Bell inequality) via a two-channel test using entangled photons.

In the GHZ experiment, a three-entangled photon state is used to test bell inequality. These experimental verification are big milestones in disproving any local hidden variable theory of quantum mechanics.

Fundamental Physics Prize Recipients: Charles Bennett, Gilles Brassard, David Deutsch and Peter Shor.

Citation: "For foundational work in the field of quantum information."

Bennett and Brassard came up with the **BB84** protocol for quantum key distribution.

David Deutsch gave the first deterministic quantum algorithm, which employs quantum superposition. It has exponential speed up if compared to classical counterparts.

Peter Shor's special contribution was to give quantum algorithms which have several practical utilities. His algorithm uses the efficiency of the quantum Fourier transform to find periods of a function. This efficiently solves the primes factorization of a number.
