SECTION 1

Realism, Locality and the "Spookiness" of Entanglement

REALISM AND LOCALITY

In classical physics the principles of "realism" and "locality" are fundamental, in effect axioms. They are as below.

The analysis begins with those two axioms because Quantum Mechanics directly and overtly denies the validity of both. Resolving that problem, that contradiction, is the objective of this work. The two axioms are comprehensively valid. The problem is to determine how the problem came about and demonstrate how it is resolved.

Realism

Realism is the principle that all objects must objectively have a pre-existing value of any of their measureable characteristics independent of any measurement that is made and before the measurement is made. The measurement cannot and does not create or initiate the value.

Locality

Locality states that an object is only directly influenced by its immediate surroundings. For an action at one location to have an influence at another non-contiguous location, something in the space between the locations must mediate the spatial separation.

Both axioms seem perfectly rational to us. To us their proof is in their statement. Of course, things are as they are without any human intervention or consent. We are not gods.

And we rely completely on the concept of cause and effect. It would be weird magic for something to be acted upon from a distant spatial separation with no accounting for that intervening space.

QUANTUM ENTANGLEMENT

Quantum entanglement is a quantum mechanical phenomenon in which the states of two or more objects have to be described with reference to each other even though the individual objects may be spatially separated. This leads to correlations between observable physical properties of the systems.

For example, it is possible to prepare two particles in a single quantum state such that when one is observed to be spin-up, the other one will always be observed to be spin-down and vice versa, this despite the fact that it is impossible to predict, according to quantum mechanics, which set of measurements will be observed.

As a result, measurements performed on one system seem to be instantaneously influencing other systems entangled with it. [But quantum entanglement does not enable the transmission of classical information faster than the speed of light.]

By definition, entanglement is a type of correlation among two or more particles (or other systems). One finds that they are entangled by measuring them and finding that the results are correlated. However, there are many subtleties. In measuring these systems, one is apt to destroy the very entanglement sought. Also, it cannot be relied on that the correlations will be strong enough to differentiate them from classical correlations. So, in practice, one knows that particles are entangled because you prepared them in a proven way. Often you can look for so-called entanglement witnesses, which are large-scale consequences of entanglement.

The more precise statement of quantum entanglement is as follows.

> In quantum mechanics, if two particles are in a state such that there is a matching correlation between two "canonically conjugate dynamical quantities", quantities like position and momentum, whose values [by Schrödinger's definition] suffice to specify all the properties of a classical system, they are termed as being "entangled".

Experiments have been conducted the results of which have been interpreted as instantaneous communication of a such 'canonically conjugate' dynamical quantity from one particle to the other, the communication exhibited as a responsive change in one particle due to an introduced change in the other particle.

That is a case of measurements performed on one system seeming to be instantaneously influencing other systems entangled with it.

Einstein famously said that he refused to believe in quantum entanglement's "spooky action at a distance". The "spooky", as Einstein called it, aspect of this is the violation of locality, the action at a distance with no intervening mediation of that separation. The "action" has been validly observed and proven so that Einstein and others sought to show that there were undetected other factors, "hidden variables", operating that did mediate the separation. They were not successful. The problem remained, "How in those cases did one particle or system of particles communicate with another spatially distant ?"