



# Quantum Entanglement !: "...spooky action at a distance."

*Edited by Paul F. Kisak*

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Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently — instead, a quantum state may be given for the system as a whole. Measurements of physical properties such as position, momentum, spin, polarization, etc., performed on entangled particles are found to be appropriately correlated. For example, if a pair of particles is generated in such a way that their total spin is known to be zero, and one particle is found to have clockwise spin on a certain axis, then the spin of the other particle, measured on the same axis, will be found to be counterclockwise; because of the nature of quantum measurement. However, this behavior gives rise to paradoxical effects: any measurement of a property of a particle can be seen as acting on that particle (e.g., by collapsing a number of superposed states); and in the case of entangled particles, such action must be on the entangled system as a whole. It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances. Such phenomena were the subject of a 1935 paper by Albert Einstein, Boris Podolsky, and Nathan Rosen, and several papers by Erwin Schrödinger shortly thereafter, describing what came to be known as the EPR paradox. Einstein and others considered such behavior to be impossible, as it violated the local realist view of causality (Einstein referring to it as "spooky action at a distance") and argued that the accepted formulation of quantum mechanics must therefore be incomplete. Later, however, the counterintuitive predictions of quantum mechanics were verified experimentally. Experiments have been performed involving measuring the polarization or spin of entangled particles in different directions, which — by producing violations of Bell's inequality — demonstrate statistically that the local realist view cannot be correct. This has been shown to occur even when the measurements are performed more quickly than light could travel between the sites of measurement: there is no light speed or slower influence that can pass between the entangled particles. Recent experiments have measured entangled particles within less than one one-hundredth of a percent of the travel time of light between them. According to the formalism of quantum theory, the effect of measurement happens instantly. It is not possible, however, to use this effect to transmit classical information at faster-than-light speeds. Quantum entanglement is an area of extremely active research by the physics community, and its effects have been demonstrated experimentally with photons, electrons, molecules the size of buckyballs, and even small diamonds. Research is also focused on the utilization of entanglement effects in communication and computation. Some metaphysical conclusions are being discussed as to whether quantum entanglement could be the closest phenomenon that science has discovered, that could represent a 'cosmic' consciousness, for lack of better terminology. This book is a comprehensive discussion of the issues and phenomenon of quantum entanglement and some of the implications that it has on the current field of quantum mechanics and in particular local realist view of causality. It is fascinating!

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