

Quantum Entanglement and its Theoretical Role in Information Transfer

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Abstract: *Quantum entanglement has been the most fascinating and fundamental aspect of quantum theory. Being a strictly non-classical phenomenon, it violates the established principle of separability and locality on which classical physics is based. The following paper entails the description of the theoretical framework and consequences of quantum entanglement as it relates to the transfer of information. An elaborate examination of the mathematical formalism of entangled states is given, such as Hilbert space products, Schmidt decomposition, and the use of density matrices in their terminology in explaining composite systems. The non-local correlations that are intrinsic to entangled states are also discussed in terms of Bell inequalities, the violation of which rules out local hidden variable interpretations in explaining quantum behaviour.*

One also focuses on such concepts as decoherence, the main theoretical pillar supporting the process of the apparent classicality outgrowth of the quantum structures. Such adverse implications on entanglement fidelity have led to the creation of powerful defending theories such as entanglement purification and quantum error correction. Lastly, entanglement and its role in establishing quantum information protocols like quantum teleportation and entanglement-based communication protocols are addressed. The protocols make use of entangled states in order to realise secure, non-local transmission of quantum information, which contradicts the traditional paradigm of communication.

This work is at best theoretical, as it conforms to the trends in the field of quantum information science. We conclude that quantum entanglement can be utilised as an irreplaceable and effective theoretical resource during the implementation of future quantum technologies and especially in the field of information science and communication.

Keywords: *Quantum entanglement, Bell inequalities, decoherence, Hilbert space, Schmidt decomposition, quantum teleportation, quantum information theory.*

