QUANTUM INFORMATION

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Introduction: What is quantum information? Subfields of quantum information science.

General characteristics of multi-partite quantum systems: Classical, Quantum and Multi-qubit systems (pure states); Measurement; Mixed states and the density matrix; Fidelity; Geometry of quantum states; Qubits; Qudits (Qunits): d-dimensional systems; Higher dimensional systems.

Interesting quantum states: Bipartite singlet state; Werner states; Schrödinger cat states; Greenberger-Horne-Zeilinger (GHZ) state.

Bell inequalities: EPR paradox; Local hidden variable models; The CHSH Bell inequality; Loopholes; Detection efficiency loophole; Locality loophole; Mermin's inequality.

Entanglement theory: Bipartite case; Pure states; Mixed states; Entanglement criteria; Partial transposition; Entanglement witnesses; Variance based criteria; Multipartite case.

Entanglement measures: Positive Operator Valued Measure; Local operations and classical communication; Von Neumann entropy; Entanglement of formation and of distillation; Bound entanglement; Requirements for entanglement measures.

No-go theorems and related issues: No-cloning Theorem; Measurement problem; Quantum teleportation; Imperfect cloning; Quantum cryptography; One-time Pad; Quantum money (70's); BB84; Ekert protocol (E91); Quantum metrology.

Introduction to Quantum Computation: Why quantum computation? Some quantum algorithms are much faster than their classical counterparts.

Quantum Circuit Model: A standard model for universal quantum computation. Quantum bits, qubits. Inputs, logical gates, outputs. Equivalent universal quantum computation models such as One-way quantum computation, Adiabatic quantum computation, etc.

DiVincenzo's criteria: 1. Well-defined qubits, 2. Initialization to a pure state; 3. Universal set of quantum gates, 4. Measurement, 5. Long coherent time.

Universal quantum computation: proof of universality: one-qubit gates plus CNOT.

Physical realizations of universal quantum computation: Introduction to proposals based on NMR, trapped Ions, linear optics, quantum dots, superconducting etc. and the current developments in experiments.

Quantum Error Correction: Introduction to passive and active Error correction protocols: decoherence free subspace, dynamical decoupling (or Spin-echo, Bang-Bang control etc.) and universal quantum error correction codes.

Quantum Algorithms: Shor’s Algorithm, Grover’s algorithm and quantum simulation.