PHY433 Quantum Information

Credit Hours: 3-0
Pre-requisite: None

Course Objectives: It is an undergraduate course which aims at introducing students to basics of quantum information theory without any prior knowledge of classical information theory. It gives an insight into the phenomena of quantum entanglement and its applications in various quantum information processes like quantum cryptography, quantum dense coding and quantum teleportation. It also introduces quantum information distribution and quantum error correction.

Core Contents: Quantum bits, quantum entanglement and its applications, quantum information theory, quantum error correction, quantum measurement.

Detailed Course Contents: Motivation; example: Quantum Random Access code, Qubits, orthogonal states; Non orthogonal states; Stern Gerlach experiment, quantum operations, Bloch Sphere; density operator for single qubit, system of qubits, density matrix, Quantum entanglement, Bell states, nonseparability of EPR pairs, Bell inequalities, maximal violation of Bell inequalities, Schmidt decomposition and entanglement, Application of entanglement: quantum no-cloning, quantum dense coding, quantum teleportation, Application of entanglement: entanglement swapping, Quantum Key Distribution, Entanglement based QKD, The Shannon entropy, classical data compression, Von Neumann entropy, quantum data compression, Accessible information, Quantifying entanglement: entanglement concentration and von Neumann entropy, Quantum error correction, bit and phase flip error correction, Shor code, Measurement of a density matrix of qubit, generalized measurements, POVM.

Course Outcomes: At the end of the course, students will be able to:

- understand quantum information carriers, the qubits, their representations and quantum operations
- phenomena of quantum entanglement and its application
- understand quantification of quantum information content and its distribution

understand quantum error correction
understand quantum measurement

Textbook:

G. Benenti, G. Casati and G. Strini, Principles of Quantum Computation and Information, Vol I&II, World Scientific 2007
John Preskill, Lecture notes on Quantum Information and Computation http://www.theory.caltech.edu/~preskill/ph219/index.html#lecture
Janos A. Bergou (JB), Tools for Quantum Information Theory, http://www.cefop.cl/schools/wpcontent/uploads/school2010/Cursos/Bergou/ConcepcionNotesV1.pdf

Reference Book: Michael A. Nielson and Isaac L. Chuang (NC), Quantum Computation and Quantum Information, Cambridge University Press, 2000.

Weekly Breakdown		
Week	Section	Topics
1	JP ch 1, 2.2 BCS 2.1	Motivation; example: Quantum Random Access code, Qubits, orthogonal states; Non orthogonal states; Stern Gerlach experiment
2	JP 2.3, 2.4 BCS 5.1	Qubit, quantum operations, Bloch Sphere; density operator for single qubit
3	Plenio	System of qubits, Density matrix
4	JP 4.1	Quantum entanglement, Bell states, non-separability of EPR pairs, Bell inequalities, maximal violation of Bell inequalities
5		Schmidt decomposition and entanglement
6	JP 4.2	Application of entanglement: quantum no-cloning, quantum dense coding, quantum teleportation
7	JP 4.2	Application of entanglement: entanglement swapping
8	JP 4.2	Quantum Key Distribution
	Handouts	Entanglement based QKD
9		**Midterm Exam**
10	BCS 5.7, 5.8	The Shannon entropy, classical data compression
11	BCS 5.9-5.11 JP 5.3	Von Neumann entropy, quantum data compression, Accessible information
12	JP 5.5 BCS 5.12	Quantifying entanglement: entanglement concentration and von Neumann entropy
13	BCS 7.1, 7.2	Quantum error correction, bit and phase flip error correction
14	BCS 7.3, 7.4	Quantum error correction: Shor code

15	JB ch. 5	Measurement of a density matrix of qubit, generalized measurements, POVM