Knight Foundation School of Computing and Information Sciences

Course Title: Advanced Quantum Information and Probability **Date:** 6/2/2024

Course Number: COT 5603

Number of Credits: 3

Subject Area: Foundations
Catalog Description: Advanced topics in quantum information theory and probability; Quantum complexity classes; Quantum channel capacity; Quantum Fourier Transform; Quantum entanglement distillation.
Textbook: Quantum Computation and Quantum Information: 10th Anniversary Edition **Authors**: Michael A. Nielsen, Isaac L. Chuang ISBN-10: 9781107002173
References: Printed lecture notes will be provided.
Prerequisites: Permission of the instructor
Corequisites: None

Type: Elective

Prerequisites Topics:

- Boolean algebra
- Probability Theory

Course Outcomes:

1. State the axioms of quantum mechanics [Remember]
2. Explain quantum superposition, entanglement, teleportation, and the uncertainty principle [Understanding]
3. Evaluate algorithms in sense of classical and quantum complexity classes [Evaluating]
4. Analyze classical-quantum and quantum-quantum channels [Analyzing]
5. Design CSS encoding and decoding mechanisms [Creating]
6. Understand quantum Fourier transforms and applications in quantum key generation [Understanding]

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Outline

Topic	No. of Lecture Hours	Outcome
• Review of Probability and Linear Algebra o Matrices, matrix operations, and traces o Random Variables o Joint Distributions and Conditional Distributions o Tensor Products	3	1
• Axioms of Quantum Mechanics o Quantum States and State Spaces o State Evolution o Projective and General Measurements o Composite State Spaces	3	2
• Quantum Protocols and Complexity Classes o Classical vs Quantum Complexity Classes o Quantum Security and Introduction to Post-Quantum Cryptography	5	3,6
• Quantum Information and Capacity o Uncertainty Principle and Quantum Ensemble o Purification o Quantum Conditional Probability o Von Neuman Entropy o Quantum Channel Capacity	3	4
• Quantum Error Correction o Bit-flip channel and Phase flip-channel o CSS Code o Decoding CSS Code	6	4,5
• Quantum Fourier Transform and Applications o Quantum Fourier Transform o Shor's Quantum Algorithm for Finding Order o Classical Post-Processing	5	5
• Quantum Entanglement Distillation and Key Generation o Classical Correlation Distillation o Entanglement Distillation o Applications in Key Generation	5	6

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Course Outcomes Emphasized in Laboratory Projects / Assignments

	Outcome	Number of Weeks
1	Linear Algebra and Probability Theory Review Exercises Outcomes: 1	1.5
2	Axioms of Quantum Mechanics Exercises Outcomes: 2	3
3	Quantum Algorithms and Complexity Exercises Outcomes: 3	3
4	Quantum Capacity and Coding Exercises Outcomes: 4,5	3.5
5	Quantum Fourier Transform Exercises Outcomes: 6	4