Knight Foundation School of Computing and Information Sciences

Course Title: Introduction to Quantum Information and Probability **Date:** 18/03/23

Course Number: COT 4604

Number of Credits: 3

Subject Area: Foundations	**Subject Area Coordinator:** Hadi Amini **email:** amini@cs.fiu.edu
Catalog Description: This course introduces basic concepts in quantum probability, quantum information, and an introduction to quantum error correction, communication, and security.	
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: (COT 3100 or MAD 2104) and (STA 2023 or STA 2122 or STA 3033)	

Type: Elective for CS (Foundations group) and CY

Prerequisites Topics:

- Boolean algebra
- Linear Algebra
- Probability Theory

Course Outcomes:

1. Perform matrix operations, trace operations, and tensor operations [Applying]
2. State the axioms of quantum mechanics [Remember]
3. Explain quantum superposition, entanglement, teleportation, and the uncertainty principle [Understanding]
4. Compare the concepts of Shannon entropy for classical sources with the Von Neuman entropy of quantum sources. [Analyzing]
5. Evaluate and quantify quantum uncertainty and channel capacity [Evaluating]
6. Design quantum error correction codes for secure communication over quantum channels. [Creating]

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Association between Student Outcomes and Course Outcomes

BS in Computing: Student Outcomes	Course Outcomes
1) Analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions.	1,2,3
2) Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program's discipline.	4,5,6
3) Communicate effectively in a variety of professional contexts.	
4) Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.	
5) Function effectively as a member or leader of a team engaged in activities appropriate to the program's discipline.	

Program Specific Student Outcomes

6) Apply computer science theory and software development fundamentals to produce computing-based solutions. [CS]	6

6) Apply security principles and practices to maintain operations in the presence of risks and threats. [CY]	6

Assessment Plan for the Course and how Data in the Course are used to assess Student Outcomes

Student and Instructor Course Outcome Surveys are administered at the conclusion of each offering, and are evaluated as described in the School's Assessment Plan: https://abet.cis.fiu.edu/

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Outline

Topic	No. of Lecture Hours	Outcome
• Basics of Probability and Linear Algebra o Matrices, matrix operations, and traces o Random Variables o Joint Distributions and Conditional Distributions o Tensor Products	6	1
• Axioms of Quantum Mechanics o Quantum States and State Spaces o State Evolution o Projective and General Measurements o Composite State Spaces	4	2
• Quantum Gates, Circuits and Protocols o Classical vs Quantum Gates o Quantum Teleportation and Superdense Coding o Quantum entanglement and the Bell state o No Cloning Principle	4	3
• Quantum Information and Probability o Uncertainty Principle and Quantum Ensemble o Purification o Quantum Conditional Probability o Von Neuman Entropy	5	3, 4
• Quantum Channels o Classical-Quantum Channels o Quantum-Quantum Channels o Quantum Security	3	5, 6
• Introduction to Quantum Channel Capacity o Classical Channel Capacity o Quantum Channel Capacity Formulation and Examples	4	5
• Quantum Error Correction o Bit-flip channel and Phase flip-channel o CSS Code o Decoding CSS Code	4	5,6

Course Outcomes Emphasized in Laboratory Projects / Assignments

	Outcome	Number of Weeks
1	Linear Algebra and Probability Theory Review Exercises Outcomes: 1	3
2	Axioms of Quantum Mechanics Exercises Outcomes: 2,3	4
3	Quantum Information and Entropy Exercises Outcomes: 3,4	4
4	Quantum Capacity Evaluation Outcomes: 5,6	2
5	Design of CSS Code Outcomes: 5,6	2

Oral and Written Communication: No significant coverage

Number of written reports:

Approximate number of pages for each report:

Number of required oral presentations:

Approximate time for each presentation:

Social and Ethical Implications of Computing Topics

No significant coverage

Topic	Class time	Student performance measures

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Theoretical Contents

Topic	Class time
Probability Theory	4.5 Hours
Linear algebra	4.5 Hours

Problem Analysis Experiences

The Coverage of Knowledge Units within Computer Science Body of Knowledge[1]

Knowledge Unit	Topic	Lecture Hours
DS. Discrete Probability	1	4.5
IAS. Linear Algebra	1	4.5
IAS. Quantum Cryptography	5,7	3
IAS. Entropy Measures	4	7.5
AR/SF. Logic Gates	4	6

[1] See the latest version of Computer Science Curricula (2013). Final Report of the IEEE and ACM Joint Task Force on Computing Curricula, available at:
https://www.acm.org/binaries/content/assets/education/cs2013_web_final.pdf