Knight Foundation School of Computing and Information Sciences

Course Title: Fundamentals of Quantum Computing **Date:** 11/7/2022

Course Number: COT 4601

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 theory, applications of quantum computing, and a review of quantum algorithms.	
Textbook: "Quantum Computing for Computer Scientists" (8th Ed) Yanofsky and Mannucci ISBN: 9780521879965	
References: "Quantum Computation and Quantum Information" (10th Ed) Nielsen and Chuang ISBN-13: 978-1-107-00217-3	
Prerequisites: (COP 3337 or COP 3804) and (COT 3100 or MAD 1100 or MAD 2104)	
Corequisites: None	

Type: Elective for CS (Foundations group), CY, IT (Application Development group)

Prerequisites Topics:

- Boolean algebra
- High level programming language constructs
- Function call/return
- Parameters of a function(method)
- Fundamental data structures

Course Outcomes:

1. Describe quantum mechanics concepts [Understanding]
2. Explain and apply linear algebra operations [Applying]
3. Discuss quantum computer systems [Understanding]
4. Analyze quantum application software [Creating]
5. Summarize the role of quantum technology in secure computing [Understanding]
6. Design and evaluate quantum programs for simple known algorithms [Creating]

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, 3, 4
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.	2
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]	5, 6
6) Apply security principles and practices to maintain operations in the presence of risks and threats. [CY]	5, 6
6) Use systemic approaches to select, develop, apply, integrate, and administer secure computing technologies to accomplish user goals. [IT]	5, 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	Course Outcomes

• Overview of Quantum Computing
  ○ Basic quantum mechanics
  ○ Classical vs Quantum systems
  ○ Quantum supremacy
  ○ Quantum computer architectures
  ○ Quantum applications
	3	1

• Introduction to Quantum theory
  ○ Complex Numbers
  ○ Linear Algebra – vector and matrix operations
	3	2

• Quantum States and Quantum Gates
  ○ Dirac notation, Bloch sphere, Hilbert space
  ○ Quantum superposition
  ○ Single qubit gates
  ○ Multiple qubit gates
  ○ Quantum entanglement, Bell state
	5	3

• Quantum Software Development
  ○ Quantum assembly language
  ○ Quantum programming languages
  ○ Quantum simulator
  ○ Design and evaluation of quantum algorithms
  ○ Complexities in real quantum system execution
	4	3, 4

• Examples of Quantum Algorithms
  ○ Shor's Factorization algorithm
  ○ Grover's unstructured search algorithm
  ○ Quantum error correcting code
	9	4, 5

• Challenges in Quantum Technology
  ○ Quantum measurement
  ○ Cloning theorem
  ○ Scalability in real quantum systems
	3	6

• Quantum Applications
  ○ Healthcare, transportation, finance, security
  ○ Quantum warfare
  ○ Post quantum cryptography
	3	

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Course Outcomes Emphasized in Laboratory Projects / Assignments

	Outcome	Number of Weeks
1	Quantum mechanics exercises Outcomes: 2	2
2	Linear algebra exercises Outcomes: 2	2
3	Quantum circuit design Outcomes: 2,3	2
4	Evaluate a standard quantum application with quantum simulator Outcomes: 4,5	2
5	Design a simple quantum application program Outcomes: 6	2

Grading Category Weights

20% quizzes

25% assignments

25% midterm exam

25% final exam

5% class participation

Grading Scale

Letter	Range%	Letter	Range%	Letter	Range%
A	95 or above	B	83 - 86	C	70 - 76
A-	90 - 94	B-	80 - 82	D	60 - 69
B+	87 - 89	C+	77 - 79	F	59 or less

Theoretical Contents

Topic	Class time
Complex number theory	0.5
Linear algebra	0.5

Problem Analysis Experiences

1.	Analyze the problem specification and formulate a quantum solution

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Solution Design Experiences

1. Identify suitable quantum gates for each problem module
2. Design of quantum application for known algorithms

Topics Schedule

Session	Week	Topics
1	wk1	Basic quantum mechanics; Classical vs Quantum systems
2	wk1	Quantum supremacy
3	wk2	Quantum computer architectures; Quantum applications
4	wk2	Complex Numbers
5	wk3	Linear Algebra: basics
6	wk3	Linear Algebra: vector and matrix operations
7	wk4	Dirac notation, Bloch sphere, Hilbert space
8	wk4	Quantum superposition
9	wk5	Single qubit gates
10	wk5	Multiple qubit gates
11	wk6	Multiple qubit gates contd.
12	wk6	Quantum entanglement
13	wk7	Bell state
14	wk7	**Mid-term exam**
15	wk8	Quantum assembly language

16	wk8	Quantum programming languages
17	wk9	Quantum simulator
18	wk9	Design and evaluation of quantum algorithms
19	wk10	Complexities in real quantum system execution
20	wk10	Shor Factorization algorithm
21	wk11	Shor Factorization algorithm contd.
22	wk11	Grover unstructured search algorithm
23	wk12	Grover unstructured search algorithm contd.
24	wk12	Quantum error correcting code
25	wk13	Challenges in Quantum Technology: Quantum measurement, Cloning theorem, Scalability in real quantum systems
26	wk13	Quantum Applications: Healthcare, transportation, finance, security
27	wk14	Quantum Applications: Quantum warfare, Post quantum cryptography
28	wk14	**Final exam**