DO NOT TYPE IN THIS BOX

Bulletin # : 3

Academic Year : 2022-23

FLORIDA INTERNATIONAL UNIVERSITY
UNIVERSITY CURRICULUM COMMITTEE
Proposal for a New Course

1. **School/College** College of Engineering and Computing

   Div./Dept. in Which Taught Knight Foundation School of Computing and Information Sciences

2. | COT | 4 | | | 3 |
   |---|---|---|---|---|
   | Alpha Prefix | 1st Digit | Last 3 Digits | "C"-lec-lab "L"-Lab | Cr. Hrs. |

   CIP Code *(Leave this blank):*

COT 4601

3. **Grading Method (select one):** ☒ Graded ☐ Pass/Fail

4a. **Course Title** Fundamentals of Quantum Computing

b. **Abbreviated course Title** *(for computer class schedules, transcripts)* Fund of Quantum Computing

LIMITED TO 25 Characters *(including spaces)*

5. **Statewide Course Numbering Subject Matter Area** Computing Theory

6. **Catalog Description/Major Topics** *(not to exceed 200 characters including spaces)*

College of Medicine and College of Law: Attach description not exceeding 1,000 characters including spaces.

This course introduces basic concepts in quantum theory, applications of quantum computing, and a review of quantum algorithms.

7. **Attach detailed syllabus course outline and course justification on separate page(s).**
8. **Prerequisite(s):** (COP 3337 or COP 3804) and (COT 3100 or MAD 1100 or MAD 2104)
9. **Corequisite(s):**
10. **Objective(s) of Course:**

Describe quantum mechanics concepts
Explain and apply linear algebra operations
Discuss quantum computer systems
Analyze quantum application software
Design and evaluate quantum programs

11. **Does this course duplicate/overlap other courses at FIU?** ☒ No ☐ Yes

    If yes, please explain:

12. **What other closely related department(s) have been consulted about this course?**

    Department of Electrical and Computer Engineering

13. **Is this course used for the assessment of a program or a certificate (if yes, then send a notification to assessment@fiu.edu)?** ☑ No ☐ Yes

PROPOSAL REQUESTED BY:

Faculty Contact Nagarajan Prabkar _____ ___/___/ 20 22
(Type name) (Signature)

prabakar@fiu.edu 305-348-2033
(Email address) (Phone number)

Chairperson (Dept./Div.) Jason Liu _____ ___/___/ 20 22
(Type name) (Signature)

Chairperson (Curr. Comm.) _____ ___/___/ 20 22
(Type name) (Signature)

College/School Dean John Volakis _____ ___/___/ 20 22
(Type name) (Signature)

Submit one original form. Attach one copy of the course justification and a draft of the course syllabus for this New Course Proposal. The syllabus should include the course description, objectives, learning outcomes, major topics, and textbooks.

Knight Foundation School of Computing and Information Sciences

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

Course Number: COT 4XXX

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]

Knight Foundation School of Computing and Information Sciences
COT 4XXX
Fundamentals of Quantum Computing

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/

Knight Foundation School of Computing and Information Sciences
COT 4XXX
Fundamentals of Quantum Computing

Outline

Topic	No. of Lecture Hours	Course Outcomes
• Overview of Quantum Computing o Basic quantum mechanics o Classical vs Quantum systems o Quantum supremacy o Quantum computer architectures o Quantum applications	3	1
• Introduction to Quantum theory o Complex Numbers o Linear Algebra – vector and matrix operations	3	2
• Quantum States and Quantum Gates o Dirac notation, Bloch sphere, Hilbert space o Quantum superposition o Single qubit gates o Multiple qubit gates o Quantum entanglement, Bell state	5	3
• Quantum Software Development o Quantum assembly language o Quantum programming languages o Quantum simulator o Design and evaluation of quantum algorithms o Complexities in real quantum system execution	4	3, 4
• Examples of Quantum Algorithms o Shor's Factorization algorithm o Grover's unstructured search algorithm o Quantum error correcting code	9	4, 5
• Challenges in Quantum Technology o Quantum measurement o Cloning theorem o Scalability in real quantum systems	3	6
• Quantum Applications o Healthcare, transportation, finance, security o Quantum warfare o Post quantum cryptography	3	

Knight Foundation School of Computing and Information Sciences
COT 4XXX
Fundamentals of Quantum Computing

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

Knight Foundation School of Computing and Information Sciences
COT 4XXX
Fundamentals of Quantum Computing

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**

FIU | Engineering & Computing

FLORIDA INTERNATIONAL UNIVERSITY

To: Mary Cossio
Faculty Senate

From: Dean or Assoc. Dean and College Curriculum Cmte. Chair

Subject: Memo in Lieu of Curriculum Chair and Dean Signatures for Bulletin #3

Date: November 24, 2022

As instructed by the Faculty Senate, this memo will serve as approval of the attached proposals for Bulletin #3 by our Curriculum Committee Chair, Alexander Afanasyev, and the Dean for College of Engineering and Computing (John L. Volakis), in lieu of physical signatures. The proposals in this Bulletin were approved by our Curriculum Committee on November 23, 2022.

In addition to the above, memos in lieu of signatures have also been included by departments unable to obtain physical signatures for their faculty contact and/or department chair.

FIU Engineering & Computing
FLORIDA INTERNATIONAL UNIVERSITY

To: Mary Cossio
Faculty Senate

From: Faculty Contact and KFSCIS Interim Director

Subject: Memo in Lieu of Curriculum Chair and Dean Signatures for Bulletin #3

Date: November 24, 2022

As instructed by the Faculty Senate, this memo will serve as approval of the attached proposals from KFSCIS for Bulletin #3 by faculty contact (Nagarajan Prabkar) and KFSCIS Interim Director (Jason Liu), in lieu of physical signatures. The proposals in this Bulletin were approved by our Curriculum Committee on November 23, 2022.

COT 4XXX Fundamentals of Quantum Computing

New Course Justification

Quantum computing is an emerging technology of national importance. Educating and training computing majors with quantum expertise will increase their career prospects and meet society's technological needs.

This elective course requires basic programming and mathematical skills as a prerequisite. All computing majors will acquire this prerequisite and be eligible to take this course. This course provides both theoretical and hands-on experience in cutting-edge quantum technology. Further, this will broaden opportunities for undergraduates to pursue graduate studies.

FW: New Quantum Computing courses

Trevor Cickovski <tcickovs@cs.fiu.edu> Mon, Nov 14, 2022 at 6:29 PM
To: Nagarajan Prabakar <prabakar@fiu.edu>, Trevor Cickovski <tcickovs@fiu.edu>, Jason Liu <liux@fiu.edu>
Cc: Masoud Sadjadi <sadjadi@fiu.edu>

Ok, sounds good -- looks like you envision just being in-person so there should not be any issue. I think we can move forward and create the course.

-Trevor

On 11/14/2022 2:06 PM, Nagarajan Prabakar wrote:

> HI Trevor,
>
> I will be teaching COP-4XXX in-person mode as an experimental course in Spring'23.
>
> Also, in future I plan to teach both courses in-person (Fall – COP5XXX and Spring – COP4XXX).
>
> Thanks
>
> --Prabu
>
> **From:** Trevor Cickovski <tcickovs@cs.fiu.edu>
> **Sent:** Monday, November 14, 2022 8:07 AM
> **To:** Nagarajan Prabakar <prabakar@fiu.edu>; Trevor Cickovski <tcickovs@fiu.edu>; Jason Liu <liux@fiu.edu>
> **Cc:** Masoud Sadjadi <sadjadi@fiu.edu>
> **Subject:** Re: FW: New Quantum Computing courses
>
> Prabu:
>
> It looks like ECE generally has no objection to your courses, they just would like them to be offered in-person.
>
> I did not see anywhere in your attachments where you insisted the courses be online? Would you have any issue with teaching them in-person? If not, it seems we are okay.
>
> Best,
>
> Trevor
>
> On 11/12/2022 7:15 PM, Nagarajan Prabakar wrote:
>
> > Hi Trevor,
> >
> > I have forwarded below the email trail with ECE about our two new quantum courses.
> >
> > For the details of our quantum courses, please review the seven attachments from my earlier email dated 11/8/22@11:50pm.
> >
> > The clear distinction between ECE and our courses are
> >
> > 1. Course focus (ECE: Quantum hardware; KFSCIS: quantum theory and algorithms)
> > 2. Prereq (both academic units have different prereq)
> >
> > Let me know what course of action to follow.
> >
> > Thanks
> >
> > --Prabu
> >
> > **From:** Aleksandr Krasnok <akrasnok@fiu.edu>
> > **Sent:** Thursday, November 10, 2022 2:05 PM

To: Nezih Pala <npala@fiu.edu>; Nagarajan Prabakar <prabakar@fiu.edu>
Subject: RE: New Quantum Computing courses

Dear Nezih,

This sounds very interesting! The only concern is that I prefer teaching in person. Let's discuss this over Zoom or in person?

Dear Prabakar, please let us know if you see how we can combine our effort in teaching quantum!

Best regards,

Alex Krasnok, Ph.D.,

Assistant Professor

Electrical & Computer Engineering

Florida International University

Room#: EC 2777

10555 W Flagler Street

Miami, FL 33174-1630

Phone: (737)781-1203

Web: https://www.krasnok.com/

GS: Alex Krasnok

From: Nezih Pala <npala@fiu.edu>
Sent: Thursday, November 10, 2022 9:12 AM
To: Aleksandr Krasnok <akrasnok@fiu.edu>; Nagarajan Prabakar <prabakar@fiu.edu>
Subject: RE: New Quantum Computing courses

Hello,

We proposed 2 quantum courses in ECE:

EEE 4423 Introduction to Quantum Computers

EEE 6429 Advanced Quantum Computers

They have been approved with their permanent course numbers.

Indeed, they are intended to focus on the hardware principles and algorithms.

I offered EEE 6429 in Spring 2022 for the first time as a fully online course.

Alex,

You are welcome to teach it. In fact, we can jointly develop both courses and teach in rotation.

Best,

Nezih Pala, PhD
Professor
Eminent Scholar Chaired Professor

Electrical & Computer Engineering
Florida International University
Room#: EC 3142
10555 W Flagler Street
Miami, FL 33174-1630
Phone: (305) 348 3016
https://insyst.fiu.edu/

From: Aleksandr Krasnok <akrasnok@fiu.edu>
Sent: Wednesday, November 9, 2022 2:44 PM
To: Nagarajan Prabakar <prabakar@fiu.edu>; Nezih Pala <npala@fiu.edu>
Subject: RE: New Quantum Computing courses

Dear Prabakar,

As I can see, the quantum courses at EE are more hardware oriented. In contrast, the COT courses are software with a focus on quantum algorithms.

Potentially, we can take advantage of both courses if students take them all together or one right after another.

BTW, I had never heard of this graduate course, *EEE 6429 - Advanced Quantum Computers*, to be teched online by Prof. Pala. I was going to teach another (special topics) course on quantum materials and technologies that I taught last spring semester.

Dear @Nezih Pala, could you please tell us more about this course? Is it given a permanent number? Have you already taught this course? Is it all online, as the Course Catalog says, or do you plan to teach it in person? As I can see, we have a good overlap between your course and mine.

Best regards,

Alex Krasnok, Ph.D.,

Assistant Professor

Electrical & Computer Engineering

Florida International University

Room#: EC 2777

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Miami, FL 33174-1630

Phone: (737)781-1203

Web: https://www.krasnok.com/

GS: Alex Krasnok

From: Nagarajan Prabakar <prabakar@fiu.edu>
Sent: Wednesday, November 9, 2022 2:22 PM
To: Aleksandr Krasnok <akrasnok@fiu.edu>
Subject: New Quantum Computing courses

Dear Alex,

I understand that ECE offers the following two courses on quantum computers:

EEE 4423 Introduction to Quantum Computers

Description: This course provides the foundations of quantum computers and quantum information systems with an emphasis on physical implementations.

Prerequisites: EEL 3120(Introduction to Linear Systems in Engineering), EEL 3135(Signals and Systems).

EEE 6429 Advanced Quantum Computers

Description: This course provides advanced principles of quantum computers and quantum information systems with in-depth analysis and state of the art physical implementations.

For computing majors, courses with quantum theory and quantum algorithm will be essential. I have prepared the following two new courses and attached their syllabi:

COT 4XXX Fundamentals of Quantum Computing

COT 5XXX Quantum Algorithms

Would you review these two course syllabi and let me know if there is any significant overlap between these new courses and ECE Quantum Computers courses.

Regards

--Prabakar

--

****

Trevor Cickovski

Associate Teaching Professor of Computer Science

Interim Associate Director, Knight Foundation School of Computing and Information Sciences (KF-SCIS)

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tcickovs@fiu.edu

"You learn more from missing a tough target than hitting an easy one."

****

--
****
Trevor Cickovski
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