New York City College of Technology, CUNY

CURRICULUM MODIFICATION PROPOSAL FORM

This form is used for all curriculum modification proposals. See the [Proposal Classification Chart](http://openlab.citytech.cuny.edu/collegecouncil/files/2014/08/2013-10-09-Proposal_Classification_Chart.pdf) for information about what types of modifications are major or minor. Completed proposals should be emailed to the Curriculum Committee chair.

|  |  |
| --- | --- |
| **Title of Proposal** | **Minor Changes for PHYS 2609 within the Applied Computational Physics program** |
| **Date** | **8/22/2018** |
| **Major or Minor** | **Minor** |
| **Proposer’s Name** | **Giovanni Ossola** |
| **Department** | **Physics** |
| **Date of Departmental Meeting in which proposal was approved** | Preliminary voting taken online 8/23/2018(to be ratified by dept. meeting on 8/30/2018) |
| **Department Chair Name** | **German Kolmakov** |
| **Department Chair Signature and Date** |  **8/22/2018** |
| **Academic Dean Name** | **Justin Vazquez-Poritz** |
| **Academic Dean Signature and Date** | 8/23/18 |
| **Brief Description of Proposal**(Describe the modifications contained within this proposal in a succinct summary. More detailed content will be provided in the proposal body. | * Change the pre-requisites of PHYS 2609
* Modify the Applied Computational Physics program requirements, to enable students to be able to choose between PHYS 2609 and PHYS 3300.
 |
| **Brief Rationale for Proposal**(Provide a concise summary of why this proposed change is important to the department. More detailed content will be provided in the proposal body).  | These changes will provide additional flexibility for students in the Applied Computational Physics program, as well as allow more students (also outside the Physics program) to access the important concepts contained in the course PHYS 2609 (Introduction to Quantum Computing). An extensive introduction to the topics in Quantum Mechanics which are needed for the purpose of PHYS 2609 is indeed provided in the first several weeks of the course, making it accessible to students with the physics and mathematics proficiency provided by PHYS 1442 and MAT 1575. |
| **Proposal History**(Please provide history of this proposal: is this a resubmission? An updated version? This may most easily be expressed as a list). | No previous history. |

Please include all appropriate documentation as indicated in the Curriculum Modification Checklist.

For each new course, please also complete the New Course Proposal and submit in this document.

Please submit this document as a single .doc or .rtf format. If some documents are unable to be converted to .doc, then please provide all documents archived into a single .zip file.

**ALL PROPOSAL CHECK LIST**

|  |  |
| --- | --- |
| Completed CURRICULUM MODIFICATION FORM including: |  |
| * Brief description of proposal
 | Y |
| * Rationale for proposal
 | Y |
| * Date of department meeting approving the modification
 | Y |
| * Chair’s Signature
 | Y |
| * Dean’s Signature
 |  Y |
| Evidence of consultation with affected departmentsList of the programs that use this course as required or elective, and courses that use this as a prerequisite. | N/A |
| Documentation of Advisory Commission views (if applicable). | N/A |
| Completed [Chancellor’s Report Form](http://openlab.citytech.cuny.edu/collegecouncil/files/2014/08/2013-10-09-Chancellor_Report_Quick_Reference_Guide1.doc). | Y |

**EXISTING PROGRAM MODIFICATION PROPOSALS**

|  |  |
| --- | --- |
| Documentation indicating core curriculum requirements have been met for new programs/options or program changes.  | N/A |
| Detailed rationale for each modification (this includes minor modifications) | Y |

**List of Courses that use this course as prerequisite.**

No courses are currently listing PHYS 2609 as a pre-requisite.

**List of the programs that use this course as required or elective.**

Currently no programs are listing PHYS 2609 as a required course. The BS in Applied Computational Physics currently lists PHYS 2609 as a suggested program elective. With the approval of the present proposal, PHYS 2609 will satisfy a requirement from the BS in Applied Computational Physics.

**Rationale for the Proposed Minor Changes**

The present proposal targets two minor curriculum changes, both related with the course PHYS 2609 (Introduction to Quantum Computing), which is currently on the City Tech catalog. We propose to change the pre-requisites of PHYS 2609 and to modify the Applied Computational Physics program requirements to allow students to take PHYS 2609 in place of PHYS 3300.

Both changes will provide additional flexibility for students in the Applied Computational Physics program in terms of available options for their plan of studies, as well as allow more students (also outside the Physics BS program) to access the important concepts contained in the course PHYS 2609. Current pre-requisites are far too advanced for the aims of a 2000-level course and preclude access to the course to most student.

An extensive introduction to the topics on Quantum Mechanics which are relevant for the purpose of PHYS 2609 is indeed provided in the first weeks of the course, making it accessible to students with the physics and mathematics proficiency provided by PHYS 1442 and MAT 1575.

Moreover, within the Applied Computational Physics program, we observed that the availability of an additional 2000-level course, as a possible alternative, would increase the flexibility of the program to adapt to the individual needs of the students, in particular for transfer students which often need alternative sequences of courses to complement their existing credits.

**Section AV: Changes in Existing Courses**

PHYS 2609 Introduction to Quantum Computing. Course offered by the Physics Department.

|  |  |  |  |
| --- | --- | --- | --- |
| **CUNYFirst Course ID** |  |  |  |
| **FROM:** |  | **TO:** |  |
| **Department(s)** |  | **Department(s)** |  |
| **Course** |  | **Course** |  |
| **Prerequisite** | ~~PHYS 2443 or PHYS 2607~~ | **Prerequisite**  | PHYS 1442 and MAT 1575 |
| **Corequisite** |  | **Corequisite** |  |
| **Pre- or corequisite** |  | **Pre- or corequisite** |  |
| **Hours** |  | **Hours** |  |
| **Credits** |  | **Credits** |  |
| **Description** |  | **Description** |  |
| **Requirement Designation** |  | **Requirement Designation** |  |
| **Liberal Arts** | [ ] Yes [ ] No  | **Liberal Arts** | [ ] Yes [ ] No  |
| **Course Attribute (e.g. Writing Intensive, Honors, etc** |  | **Course Attribute (e.g. Writing Intensive, Honors, etc** |  |
| **Course Applicability** | [ ] Major[ ] Gen Ed Required[ ] English Composition[ ] Mathematics[ ] Science[ ] Gen Ed - Flexible[ ] World Cultures[ ] US Experience in its Diversity[ ] Creative Expression[ ] Individual and Society[ ] Scientific World[ ] Gen Ed - College Option[ ] Speech[ ] Interdisciplinary [ ] Advanced Liberal Arts | **Course Applicability** | [ ] Major[ ] Gen Ed Required[ ] English Composition[ ] Mathematics[ ] Science[ ] Gen Ed – Flexible[ ] World Cultures[ ] US Experience in its Diversity[ ] Creative Expression[ ] Individual and Society[ ] Scientific World[ ] Gen Ed - College Option[ ] Speech[ ] Interdisciplinary [ ] Advanced Liberal Arts |
| **Effective Term** | Spring, 2019 |  |  |

**Rationale:** This change will provide additional flexibility for students in the Applied Computational Physics program, as well as allow more students (also outside the Physics program) to access the important concepts contained in the course PHYS 2609 (Introduction to Quantum Computing). An extensive introduction to the topics ion Quantum Mechanics which are needed for the purpose of PHYS 2609 is indeed provided in the first weeks of the course, making it accessible to students with the physics and mathematics proficiency provided by PHYS 1442 and MAT 1575.

**Section AIII: Changes in Degree Programs**

**The following revisions are proposed for the BS in Applied Computational Physics**

**Program: the BS in Applied Computational Physics**

**Program Code:**

**Effective Date: Spring 2019**

|  |  |
| --- | --- |
| **FROM:** | **TO:** |
| **Applied Computational Physics (ACP) Requirements: 16 cr**~~PHYS 3300 Computational Fluid Dynamics -- 3 cr~~ PHYS 3600 Machine Learning for Physics and Astronomy -- 3 cr PHYS 4100 Computational Methods -- 4 cr PHYS 4150 Computational Methods Laboratory -- 2 cr PHYS 4200 Internship/Real Research Experience – 4 cr**~~Program Electives: 9 cr~~** | **Applied Computational Physics (ACP) Requirements: 16-17 cr**PHYS 3300 Computational Fluid Dynamics -- 3 cr OR PHYS 2609 Introduction to Quantum Computing -- 4cr PHYS 3600 Machine Learning for Physics and Astronomy -- 3 cr PHYS 4100 Computational Methods -- 4 cr PHYS 4150 Computational Methods Laboratory -- 2 cr PHYS 4200 Internship/Real Research Experience – 4 cr**Free Elective Courses: Take as needed to equal 120 credits1** |

1 The wording chosen for the remaining elective credits is more general and reflects the structure of the Program Checklists present in the College Catalog 2018. This is indeed independent for the present proposal.

**Rationale:** These changes will provide additional flexibility for students in the Applied Computational Physics program in terms of available options for their plan of studies, allowing them to access the important concepts contained in the course PHYS 2609. Moreover, by advising students within the Applied Computational Physics program, we observed that the availability of an additional 2000-level course, as a possible alternative, would increase the flexibility of the program to adapt to the individual needs of the students, in particular for transfer students which often need alternative sequences of courses, to complement their existing credits.

NEW YORK CITY COLLEGE OF TECHNOLOGY

CITY UNIVERSITY OF NEW YORK

PHYSICS DEPARTMENT

Section Number: Instructor:

Email Address: Office hours:

**Course Name:** PHYS 2609 – Introduction to Quantum Computing

**Credit Hours:** 4 credit (4 hour)

**Prerequisites:** PHYS 1442 and MAT 1575

**Course Description:** The course provides an introduction to the field of quantum computing. While very much a technology of the future, the course will examine some of the possibilities that the quantum world offers in advancing the capabilities of computers and how our notion of information has evolved. Topics covered include elements of Boolean algebra and classical logic gates, qubits and hypothesis of quantum mechanics, introduction to quantum algorithms, quantum teleportation and it application, quantum entanglemen, statistical and adiabatic quantum computation, physical realizations of logic quantum gates in quantum system.

**Text:**

* **An introduction to Quantum Computing** by *Phillip Kaye, Raymond Laflamme and Michele Mosca, Oxford University Press*
* Quantum Computing, Noson Yanofsky, Mirco Mannucci, Cambridge University Press.
* Lecture notes will be distributed

Complementary text:

* **Introduction to Quantum Computers** by *Gennady Berman, Gary Doolen, Ronnie Mainieri and Vladimir Tsifrinovich, Word Scientific*

**Learning Outcomes and Assessment Measures**

After successful completion of this course, students will demonstrate competencies in:

|  |  |
| --- | --- |
| Learning Objectives | Assessment: Instructional Activity, Evaluation Methods and Criteria |
| Students will acquire the basic principles that underlie quantum computing and gain insights into some of the fascinating revolutions that are currently taking place | In-class lectures and discussions, demonstrations, reading, students will be expected to present their material during tutorial classes in an interactive mode, homework assignments, short quizzes. |
| Students understand main ideas of quantum computing and quantum algorithms | In-class discussions, demonstrations, reading, group discussion, homework assignments, short quizzes. |
| Physical realizations of logic quantum gates in Quantum System | In-class discussions, course project, reading, group discussion. Students, in groups of two or three, will also be expected to carry out literature reviews of selected chapters of text books and journal articles. |
| Engage students to critically analyze some of the bizarre implications of the quantum world for quantum computing | In-class discussions, reading, group discussion, homework assignments, course project |

**Teaching/Learning Methods**

* Lecture presentations and demonstrations
* Blackboard group discussions
* Reading and multimedia viewing
* Homework assignments, midterm and final exams

**Grading Procedures**

Homework assignments 20%

Two midterm exams 40%

Course Project short essays and presentation) 20%

Final exam 20%

HOMEWORK ASSIGNMENTS and COURSE PROJECT

Percent of Grade: 20%+20%

The course will consists of weekly lectures that will showcase some of the major developments in the field. Students will be assigned chapter reading and homework problems for each topic in the course. The goal of the homework assignment is to assess and stimulate students’ qualitative and quantitative understanding of the relevant concepts. Each student will have to submit a separate assignment. The ideas and discussions broached during lectures will be further reinforced in tutorials where students will undertake to solve problems and make oral presentations of the Course project. Assessment activities will include presentation of tutorial exercises and short quizzes. Students will be expected to present their material during tutorial classes in an interactive mode. Students, in groups of two or three, will also be expected to carry out literature reviews of selected journal articles and present their work during tutorial sessions.

In Class Exams

Percent of grade: 60%

Two non-cumulative midterm exams. An average of the two examinations will count 40% toward your total PHYS 2609 grade. A cumulative final examination will count 20% toward total PHYS 2609 grade. The exams will cover reading assignments, lectures, and classroom discussions.

**Course Weekly Calendar**

|  |  |
| --- | --- |
| Week | Topic |
| 1 | Course overview. Elements of Boolean Algebra and Binary System |
| 2 | Classical Logic Gates and Logic gate symbols (AND gate, OR gate, NOT gate, NAND gate, NOR gate, EXOR gate, **EXNOR gate)** |
| 3 | **Circuit Models** |
| 4 | **Linear Algebra and Dirac Notation*** Hilbert Space
* Operators
* The Spectral theorem
* Functions of Operators, Tensor Products
* The Schmidt Decomposition Theorem
 |
| 5 | Qubits and hypothesis of Quantum mechanics* + The state of a quantum system
	+ Time evolution postulate
	+ Superposition and composite System
	+ Measurement postulate
	+ Mixed states and general quantum operation
 |
| 6 | Quantum model of computation* + Quantum gates (one and two qubits gate)
	+ Universal set of quantum gates
	+ Measurements with quantum circuits
 |
| 7 | Exam; Superdense coding |
| 8 | Quantum Entanglement |
| 9 | Introduction to Quantum algorithms* + Phase kick-back
	+ The Deutsch Algorithm
	+ The Deutsch-Jozsa Algorithm
	+ Quantum phase estimation and quantum Fourier Transformation.
 |
| 10 | Introduction to Quantum algorithms* + Eigenvalue Estimation and finding orders
	+ Shor’s algorithm
	+ Algorithms based on amplitude amplification. Grover’s quantum Search algorithm
	+ Search without knowing the success probability.
 |
| 11 | Exam 2. Quantum Error Correction. |
| 12 | Statistical Quantum computation. |
| 13 | Statistical Quantum computation. Adiabatic Quantum Computation |
| 14 | Physical realizations of logic quantum gates in Quantum System (based on homework)* Ion Trap Quantum Computer.
* Solid State Spin Quantum Computer.
* Superconductor Quantum Computer.
* Topological Quantum Computer.
* Liquid State Quantum Computer
 |
| 15 | Course project presentation. Final exam |

**NEW** **YORK CITY COLLEGE OF TECHNOLOGY POLICY ON ACADEMIC INTEGRITY**

St*u*dents and all others who work with information, ideas, texts, images, music, inventions, and other intellectual property owe their audience and sources accuracy and honesty in using, crediting, and citing sources. As a community of intellectual and professional workers, the College recognizes its responsibility for providing instruction in information literacy and academic integrity, offering models of good practice, and responding vigilantly and appropriately to infractions of academic integrity. Accordingly, academic dishonesty is prohibited in The City University of New York and at New York City College of Technology and is punishable by penalties, including failing grades, suspension, and expulsion. The complete text of the College policy on Academic Integrity may be found in the catalog.

**Grading Policy:**

A 93-100

A- 90-92.9

B+ 87-89.9

B 83-86.9

B- 80-82.9

C+ 77-79.9

C 70-76.9

D 60-69.9

F 59 and below