SFU GRADUATE AND POSTDOCTORAL STUDIES

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MEMORANDUM

ATTENTION Senate

DATE April 30, 2020

FROM Jeff Derksen,
Chair of Senate Graduate Studies
Committee (SGSC)

RE: New Course Proposal

For information:

Acting under delegated authority at its meeting of April 7, 2020, SGSC approved the following new course, effective **Spring 2021:**

Faculty of Science

Department of Physics

1) New course: PHYS 816 Quantum Information

Senators wishing to consult a more detailed report of curriculum revisions may do so on the Senate Docushare repository at https://docushare.sfu.ca/dsweb/View/Collection-12682

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MEMORANDUM

ATTENTION	Senate Graduate Studies Committee	**DATE**	March 11, 2020
FROM	Michael Silverman, Associate Dean of Research and Graduate Studies	**PAGES**	1
RE:	New Course: PHYS 816		

The following curriculum item has been approved by the Faculty of Science and are forwarded to the Senate Graduate Studies Committee for approval. These curriculum items should be effective for **Spring 2021.** Please include them on the next SGSC agenda.

Department of Physics

PHYS 816 Quantum Information

Please see attached memo from M. Kennett, Graduate Chair, Physics, for details.

Michael A. Silverman, Ph.D.
Faculty Graduate Chair

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August 23, 2019

Dear Science Graduate Chairs,

I am writing to propose a new graduate course in the Physics Department, PHYS 816, titled "Quantum Information Science". The rationale for the introduction of this new course is that quantum computation and quantum information are important and rapidly growing areas of Physics. SFU hosts a world-leading group in this research area and has strong connections with D:wave systems, a leading company in this field, located in Burnaby. We believe that there will be robust demand for this course – of the approximately 70 students in the graduate program in Physics, about a quarter (18) would be expected to take this course during their graduate career. In addition, this course would be cross-listed with a proposed upper level undergraduate course, PHYS 416 with the same title. When both undergraduate and graduate students take the course, graduate students will be required to perform additional work either through an additional literature review and/or more extensive homework problems. The existing expertise in the SFU Physics department means that there are multiple faculty members who could teach this course, and train students in what is likely to be an important area of Physics in the 21st Century. I attach a course outline on the following page.

Yours sincerely,

MP Kennett

Malcolm Kennett

Associate Professor and Graduate Chair
Department of Physics
Simon Fraser University

GRADUATE AND POSTDOCTORAL STUDIES

New Graduate Course Proposal

Course Subject (eg. PSYC) PHYS	Number (eg. 810) 816	Units (eg. 4) 3

Course title (max. 100 characters)

Quantum Information Science

Short title (for enrollment/transcript - max. 30 characters) Quantum Information

Course description for SFU Calendar (course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description)

Includes topics such as qubits, density matrices, mixed states, entanglement, basic quantum algorithms, quantum cryptography, computational models and complexity, introductory quantum error correction, and applications.

Rationale for introduction of this course

Quantum Computation and Quantum Information are important and rapidly growing areas of Physics. Additionally, SFU hosts a world leading group in this research area. Hence we intend to take advantage of this expertise to introduce a course to train students in what is likely to be an important area of Physics in the 21st Century.

Term of initial offering (eg. Fall 2019) Spring 2021	Course delivery (eg. 3 hrs/week for 13 weeks) 3hrs/week for 13 weeks
Frequency of offerings/year Once every two years	Estimated enrollment per offering 5

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

Students with a credit for PHYS 416 may not take this course for further credit

Prerequisite and/or Corequisite Recommended prerequisite: PHYS 385 and either PHYS 384 or MATH 314 and 419, or equivalent, with a minimum grade of C-.

Criminal record check required? ☐ Yes if yes is selected, add this as prerequisite

Additional course fees? ☐ Yes ☑ No

Campus where course will be taught ☑ Burnaby ☐ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components * ☑ Lecture ☐ Seminar ☐ Lab ☐ Independent ☐ Capstone ☐ ____

Grading Basis ☑ Letter grades ☐ Satisfactory/ Unsatisfactory ☐ In Progress / Complete

Repeat for credit? ☐ Yes ☑ No	Total repeats allowed? 0	Repeat within a term? ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	Final exam required? ☐ Yes ☑ No	Capstone course? ☐ Yes ☑ No

Combined with a undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and the additional course requirements for graduate students:

Undergraduate course: PHYS 416. Graduate students will be required to perform an additional literature review module and/or homework problems

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course
Stephanie Simmons, Paul Haljan, Igor Herbut, Malcolm Kennett
Additional faculty members, space, and/or specialized equipment required in order to offer this course

CONTACT PERSON

Academic Unit / Program	Name (typically, Graduate Program Chair)	Email
Physics	Malcolm Kennett	physgchr@sfu.ca

ACADEMIC UNIT APPROVAL

A course outline must be included.

Non-departmentalized faculties need not sign

	Signature	Date
Graduate Program Committee Malcolm Kennett	MP Kennett	23rd August 2019
Department Chair Jeff Sonier		Sept. 3, 2019

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

Overlap check done? [x] YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee	Signature	Date
Michael Silverman	Michael A. Silverman	3.11.2020

A library review will be conducted. If additional funds are necessary, DGS will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee	Signature	Date
Jeff Derksen		04-30-2020

ADMINISTRATIVE SECTION (for DGS office only)

Library Check: ____________

Course Attribute: ____________

Course Attribute Value: ____________

Instruction Mode: ____________

Attendance Type: ____________

If different from regular units:

Academic Progress Units: ____________

Financial Aid Progress Units: ____________

Course Outline: PHYS 816

Topics to be covered:

- qubits
- density matrices
- mixed states
- entanglement
- basic quantum algorithms
- quantum cryptography
- computational models and complexity
- introductory quantum error correction
- applications

Textbook: Neilson and Chuang "Quantum Computation and Quantum Information", optional.

Grading Scheme:

Assignments	40%
Midterm	10%
Final Exam	35%
Project	15%

Assignments:
There will usually be 6 assignments. Many of the assignments will involve computer simulation of small numbers of qubits. Examples of topics covered in each assignment are:

1. Matrix formulation of quantum systems, quantum measurements, single-qubit manipulations, pure states.
2. Exponentiated matrices, pure and mixed states, quantum circuits, thermal states.
3. Single qubit gates, simple quantum circuits
4. Entanglement tests, QKD protocols and physical security, mixed-state quantum circuits, tomography
5. Error-correction circuits, 2-qubit interactions, quantum eraser protocols
6. Error-correction stabilizers, error-correction codes, variational quantum eigensolve, quantum approximate optimization

When PHYS 416 and PHYS 816 are offered together, PHYS 816 students will complete all of the questions for PHYS 416 students with an additional question that explores a topic in greater depth than PHYS 416 on each assignment.

Midterm and Final Exam:
When PHYS 416 and PHYS 816 are offered together, the midterm and final exam will be the same for both courses.

Projects:
Each student will be required to complete a project on a topic in quantum information science. For their project, each student will give a presentation and write a report. The presentation will be 30 minutes in a tutorial-style on a topic of their choice, to be agreed upon in advance with the instructor. The material covered in the presentations will be tested in assignments and the final exam.

Four weeks before the presentation, students will be required to provide an outline of their presentation to the instructor. At the time of their presentation they will be required to hand in a 4-6 page report on their chosen topic.

Any topic related to quantum information science will be considered, but some suggested topics are listed below:

- Quantum Fourier transform
- Quantum phase estimation
- Grover's search algorithm
- Quantum finite automata
- HHL algorithm
- QAOA algorithm
- Shor's algorithm
- RSA (classical)
- Quantum complexity classes and algorithm categorization
- Quantum-safe classical cryptography
- Overheads: physical vs logical qubit
- Photon memories
- Entanglement distillation
- Quantum computing hardware platforms
- Magic states and magic state distillation
- Quantum authentication
- Weak values
- Boson sampling
- Quantum programming/software/compilers
- Quantum Chemistry/simulation algorithms
- Information and entropy
- Quantum repeaters
- Quantum radar
- Quantum telescopes

Course Outline: PHYS 416

Topics to be covered:

- qubits
- density matrices
- mixed states
- entanglement
- basic quantum algorithms
- quantum cryptography
- computational models and complexity
- introductory quantum error correction
- applications

Textbook: Neilson and Chuang "Quantum Computation and Quantum Information", optional.

Grading Scheme:

Assignments	45%
Midterm	15%
Final Exam	40%

Assignments:
There will be roughly 6 assignments. Many of the assignments will involve computer simulation of small numbers of qubits. Examples of topics covered in each assignment are:

1. Matrix formulation of quantum systems, quantum measurements, single-qubit manipulations, pure states.
2. Exponentiated matrices, pure and mixed states, quantum circuits, thermal states.
3. Single qubit gates, simple quantum circuits
4. Entanglement tests, QKD protocols and physical security, mixed-state quantum circuits, tomography
5. Error-correction circuits, 2-qubit interactions, quantum eraser protocols
6. Error-correction stabilizers, error-correction codes, variational quantum eigensolve, quantum approximate optimization