# Request for Addition of New Course

## Proposed Course Description

<table>
<thead>
<tr>
<th>Rubric &amp; No.</th>
<th>Title</th>
<th>Quantum Information Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 7347</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Short Title (≤ 19 characters)</th>
<th>Q U A N T U M I N F O R T H E O R Y</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Semester Hours of Credit</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>If combination course type, # hrs. of credit for</td>
<td>Lecture: 3</td>
</tr>
<tr>
<td>Repeat Credit Max. (If repeatable):</td>
<td>0 credit hours</td>
</tr>
<tr>
<td>Graduate Credit?</td>
<td>Yes</td>
</tr>
<tr>
<td>Credit will not be given for this course and:</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Course Type (Indicate hours in the appropriate course type.)**

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Lab</th>
<th>Seminar</th>
<th>Recitation</th>
<th>Lec/Rec</th>
<th>Lec/Sem</th>
<th>Lec/Lab</th>
<th>Res/Ind</th>
<th>Clin/Prac</th>
<th>Intern</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum enrollment per section: (Use integer, e.g. 25 not 20-30)</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading</td>
<td>Letter Grade</td>
</tr>
</tbody>
</table>

**(Attach justification if the proposed course will not hold a final exam during examination week.)**

**Course Description:**

Concise catalog statement exactly as you wish it to appear in the General Catalog.

PhyS 7347 Quantum Information Theory (3) Classical and quantum methods for data compression and communication over channels, measurement theory and entropy.

## Budget Impact (If answer to any question is "Yes", Attach Explanation.)

<table>
<thead>
<tr>
<th>If this course is approved, will additional staff be needed?</th>
<th>Yes</th>
<th>No</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will additional space, equipment, special library materials or other major expense be involved?</td>
<td>Yes</td>
<td>No</td>
<td>X</td>
</tr>
</tbody>
</table>

**Academic Affairs Approval:**

## Attachments (Attach the following to your proposal)

**Justification:** Justification must explain why this course is needed and how it fits into the curricula. Will the course duplicate other courses?

**Syllabus:** Including 14 week outline of the subject matter; titles of text, lab manual, and/or required readings; grading scale and criteria (For 4000-level, specify graduate student grading criteria if requirements differ for graduate and undergraduate students).

## Approvals

<table>
<thead>
<tr>
<th>Department Faculty Approval Date</th>
<th>3/7/17</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Faculty Approval Date</td>
<td></td>
</tr>
</tbody>
</table>

**Department Chair Signature**

**Graduate Dean Signature**

**College Dean Signature**

**Chair, F S & C Committee**

**Academic Affairs Approval**

<table>
<thead>
<tr>
<th>Erin Doherty</th>
<th><a href="mailto:edoherty1@lsu.edu">edoherty1@lsu.edu</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>College Contact</td>
<td>E-mail</td>
</tr>
</tbody>
</table>

**Effective 16/11**
PHYS 7347 Attachment
FORM A: REQUEST TO ADD A COURSE

Justification: Quantum information theory now represents a core component of the education of a theoretical physicist. Sophisticated concepts from quantum information are increasingly being used in other diverse areas of physics such as condensed matter physics, quantum optics, thermodynamics, and gravitational physics. As such, it is timely to train our graduate students in this area so that they can speak the basic language of quantum information. At the same time, a variety of quantum technologies such as quantum key distribution and quantum metrological sensors are actively being developed, and the core theory underlying them is quantum information. Finally, quantum information theory gives a novel, intuitive approach to understanding foundational aspects of quantum mechanics, and as such, this course naturally complements more traditional approaches that begin with the Schrödinger equation and go all the way to solving the hydrogen atom. This class was taught as a special topics class in Fall 2013 and Fall 2015 with enrollments at 8 and 16. Now that we have established that this course can be regularly offered, we want a course number for it.

Final Exam: This course will have a final exam in the form of a final project, consisting of a presentation and a report. The final project is assigned 1.5 months in advance of the final day of class. The final presentation and written report are to summarize a recent research topic in quantum information theory. This is a graduate-level course, and as such, graduate students gain valuable experience from presenting a research topic, which often is one of the most important skills to be developed during graduate school.

Homeworks: Students will also be graded based on their performance on 4-5 challenging homework assignments, which often can take anywhere between 5-10 hours to complete each. The homework assignments are given every 2-3 weeks and consist of 10-15 detailed problems to be worked out. The instructor grades the homework assignments. Each problem is graded as follows: two points for a complete solution, one point for some effort, and zero points for no attempt. Of course, there is some grey area: sometimes a 1.5 or 0.5 will be given as a score on a problem. The score for all problems on a homework assignment are added up and then translated to a score out of 100. Then all of the scores for the homework assignments are added and translated to a score out of 75 points, in a typical way.

Pre-/Co-requisites: This course is not a pre-requisite or co-requisite to any other course.

Sample syllabus: A sample syllabus is attached.
Quantum Information Theory
PHYS 7347
Professor Mark M. Wilde
Fall 2017

Course Description: Classical and quantum methods for data compression and communication over channels, measurement theory, and entropy.

Office: 447 Nicholson Hall

Contact information:
Phone: (225) 578-4323
Email: mwilde@lsu.edu


Material: This course introduces the subject of communication with quantum systems. Quantum information theory exploded in 1994 when Peter Shor published his algorithm that can break RSA encryption codes. Since then, physicists, mathematicians, and engineers have been determining the ultimate capabilities for quantum computation and quantum communication. In this course, we study the transmission of information over a noisy quantum communication channel. In particular, you will learn about quantum mechanics, entanglement, teleportation, entropy measures, and various capacity theorems involving classical bits, qubits, and entangled bits.

Course Outline:

Week 1: Introduction to Quantum Information Theory, Entropy and Shannon Data Compression
Week 2: Shannon’s Channel Coding Theorem (Part I), Shannon’s Channel Coding Theorem (Part II)
Week 3: Noiseless Quantum Theory, CHSH Game and Bell’s Theorem
Week 4: Density Operators, Unitaries, and Measurements, POVMs, Partial Trace, and Separable States
Week 5: Choi-Kraus Theorem for Quantum Channels, Quantum Channels are All Encompassing
Week 6: Three Noiseless Protocols, Coherent Communication and Purification
Week 7: Isometric Extensions, Trace Distance
Week 8: Trace Distance and Fidelity, Gentle Measurement
Week 9: Classical Entropies, Quantum Entropies
Week 10: Quantum Relative Entropy, Quantum Relative Entropy and Recoverability
Week 11: Quantum Data Compression, Entanglement Concentration
Week 12: Classical Capacity, Classical Capacity (Cont.)
Week 13: Entanglement-Assisted Capacity, Family of Quantum Protocols
Week 14: Trade-Off Coding, Final Presentations

Grading: There will be five assignments and a final presentation & report. The final presentation and report will serve as the final exam for the course.

Assignments 75%
Presentation and Final Report 25%

LSU letter grades will be assigned according to the following table. Your end of semester numerical grades are rounded up to whole numbers (for example, 94.49 = 94, 94.50 = 95)

97-100% A+,
94-97% A,
90-94% A−,
85-90% B+,
80-85% B,
75-80% B−,
70-75% C+,
65-70% C,
60-65% C−,
57-60% D+,
54-57% D,
50-54% D−,
less than 50%, F

Description of Activities that will be Graded:

Homework Assignments: Homework will be handwritten assignments, and the homework grade will be calculated as an average of the individual assignments. In more detail, students will be graded based on their performance on 5 challenging homework assignments, which often can take anywhere between 5-10 hours to complete each. The homework assignments are given every 2-3 weeks and consist of 10-15 detailed problems to be worked out. The instructor grades the homework assignments. Each problem is graded as follows: two points for a complete solution, one point for some effort, and zero points for no attempt. Of course, there is some grey area: sometimes a 1.5 or 0.5 will be given as a score on a problem. The score for all problems on a homework assignment are added up and then translated to a score out of 100. Then all of the scores for the homework assignments are added and translated to a score out of 75 points, in a typical way.

Final project: Each student should find a recent research paper from the quantum information literature and read it carefully. The goal is then to deliver a research-level presentation about the paper and prepare a final report that summarizes the contents of the research paper. It is also possible to pursue an original research topic for the final project. *The paper or subject for the final project should be submitted for approval by the end of the fifth week of class.*

For the presentation: Each student should take no more than 15 minutes to present. This means no more than 8 slides in Powerpoint (not counting a title slide).

Adversarial review: During the presentations, each person should ask at least two questions at minimum of your peers. There will be 5 minutes for questions after each presentation.

For the report: Each student should turn in a final report. This consists of an introduction to the topic of the paper, a review of some of the technical details, what challenges needed to be overcome, and a summary of what are the open questions for future research. Five pages single-spaced is a reasonable minimum requirement for the report.

Expectations

LSU’s general policy states that for each credit hour, you (the student) should plan to spend at least two hours working on course related activities outside of class. Since this course is for three credit hours, you should expect to spend a minimum of six hours outside of class each week working on assignments for this course. For more information see: [http://catalog.lsu.edu/content.php?catoid=12&navoid=822](http://catalog.lsu.edu/content.php?catoid=12&navoid=822).

**LSU student code of conduct**

The LSU student code of conduct explains student rights, excused absences, and what is expected of student behavior. Students are expected to understand this code as described here: [http://students.lsu.edu/saa/students/code](http://students.lsu.edu/saa/students/code). Any violations of the LSU student code will be duly reported to the Dean of Students.

**Disabilities**

Louisiana State University is committed to providing reasonable accommodations for all persons with
disabilities. The syllabus is available in alternate formats upon request.

If you have a disability that may have some impact on your work in this class and for which you may require accommodations, please see a staff member in Disability Services so that such accommodations can be considered. Students that receive accommodation letters, please meet with me to discuss the provisions of those accommodations as soon as possible.

Academic Success

The primary ingredients of your academic success are attending class, managing your time efficiently, taking good notes, and developing good critical thinking and communication abilities. LSU has a number of excellent resources that will assist you in developing these skills. The place to begin is the Center for Academic Success (http://students.lsu.edu/academicsuccess). The CAS offers guidance on what learning strategies are best suited to your talents, tutoring in the basic subjects, and workshops on a variety of topics, from note taking to time management. Communication Across the Curriculum (http://cxc.lsu.edu) assist students in developing the communication skills necessary for academic and professional success. Finally, with respect to professional success, the LSU Olindé Career Center (http://students.lsu.edu/careercenter) can assist you in choosing a major and a profession that best suits your talents and passions and help you develop a career plan to ensure success when you graduate from LSU.
**REQUEST FOR ADDITION OF NEW COURSE**

**Department:** Physics and Astronomy  
**College:** Science  
**Date:** 3/8/17

**PROPOSED COURSE DESCRIPTION**

<table>
<thead>
<tr>
<th>Rubric &amp; No.</th>
<th>PHYS 7348</th>
<th>Title</th>
<th>Quantum Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Title (≤ 19 characters)</td>
<td>Q U A N T U M C O M P U T A T I O N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semester Hours of Credit</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If combination course type, # hrs. of credit for Lecture:</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab/Sem/Rec:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeat Credit Max. (If repeatable):</td>
<td>0 credit hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduate Credit? X</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Credit will not be given for this course and:</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Course Type (Indicate hours in the appropriate course type.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td>Lab</td>
<td>Seminar</td>
<td>Recitation</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum enrollment per section: (use integer, e.g. 25 not 20-30)</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grading</td>
<td>Letter Grade X</td>
<td>Pass/Fail</td>
<td>Final Exam:**</td>
</tr>
<tr>
<td><strong>(Attach justification if the proposed course will not hold a final exam during examination week.)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Course Description:**

(Complete catalog statement exactly as you wish it to appear in the General Catalog)

**PHYS 7348 Quantum Computation (3)** Turing machines, classical and quantum models of computation, NP-completeness, theorems and algorithms for quantum computation.

---

**BUDGET IMPACT (IF ANSWER TO ANY QUESTION IS "YES", ATTACH EXPLANATION.**

| If this course is approved, will additional staff be needed? | Yes | No X |
| Will additional space, equipment, special library materials or other major expense be involved? | Yes | No X |
| Academic Affairs Approval: | (Date) |

**ATTACHMENTS (ATTACH THE FOLLOWING TO YOUR PROPOSAL)**

**JUSTIFICATION:** Justification must explain why this course is needed and how it fits into the curriculum. Will the course duplicate other courses?

**SYLLABUS:** Including 14 week outline of the subject matter; titles of text, lab manual, and/or required readings; grading scale and criteria (For 4000-level, specify graduate student grading criteria if requirements differ for graduate and undergraduate students).

---

**APPROVALS**

<table>
<thead>
<tr>
<th>Department Faculty Approval Date</th>
<th>3/7/17</th>
<th>College Faculty Approval Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department Chair Signature</td>
<td>(date)</td>
<td>College Dean Signature</td>
</tr>
<tr>
<td>Michelle J. Mason</td>
<td>10/5/17</td>
<td>Chair, FS C &amp; C Committee</td>
</tr>
<tr>
<td>Erin Doherty</td>
<td><a href="mailto:edoherty@lsu.edu">edoherty@lsu.edu</a></td>
<td>Academic Affairs Approval</td>
</tr>
</tbody>
</table>

E-mail
PHYS 7348 Attachment  
FORM A: REQUEST TO ADD A COURSE

Justification: Quantum computation is an interdisciplinary subject based on the principles of computation and quantum mechanics. The great promise of a quantum computer is that it would in principle be able to solve problems believed to be intractable on "classical" computers in existence today, by making use of quantum-mechanical features such as superposition and entanglement. There is currently an international effort underway in university, government research lab, and industrial settings to build a quantum computer. At the same time, Moore's law is expected to break down within a decade or so, and quantum-mechanical effects will be unavoidable. This suggests that we should try to harness these effects for computational purposes. The purpose of this course is to train graduate students in the fundamentals of quantum computation to enable them to participate in the international effort to build and understand quantum computers. At the same time, the course will give them a different perspective on traditional fields such as quantum mechanics and computational theory. Pilot versions of this course have attracted students from a variety of disciplines, including physics, mathematics, computer science, and electrical engineering, and thus it is in line with the university's strategic plan to enhance interdisciplinary activities at LSU. This course was taught in Spring 2014 and Spring 2016 as PHYS 7895, with enrollments of 6 and 5. Since we have a large research group in this area there is a continuing demand for this course, so it needs its own course number.

Final Exam: This course will have a final exam in the form of a final project, consisting of a presentation and a report. The final project is assigned 1.5 months in advance of the final day of class. The final presentation and written report are to summarize a recent research topic in quantum computation. This is a graduate-level course, and as such, graduate students gain valuable experience from presenting a research topic, which often is one of the most important skills to be developed during graduate school.

Homeworks: Students will also be graded based on their performance on 4-5 challenging homework assignments, which often can take anywhere between 5-10 hours to complete each. The homework assignments are given every 2-3 weeks and consist of 10-15 detailed problems to be worked out. The instructor grades the homework assignments. Each problem is graded as follows: two points for a complete solution, one point for some effort, and zero points for no attempt. Of course, there is some grey area: sometimes a 1.5 or 0.5 will be given as a score on a problem. The score for all problems on a homework assignment are added up and then translated to a score out of 100. Then all of the scores for the homework assignments are added and translated to a score out of 75 points, in a typical way.

Pre-/Co-requisites: This course is not a pre-requisite or co-requisite to any other course.

Sample syllabus: A sample syllabus is attached.
Quantum Computation
PHYS 7348
Professor Mark M. Wilde
Fall 2017

Course Description: Turing machines, classical and quantum models of computation, NP-completeness, theorems and algorithms for quantum computation.

Office: 447 Nicholson Hall

Contact information:
Telephone: (225) 578-4323
Email: mwilde@lsu.edu


Material: The field of quantum computation exploded in 1994 when Peter Shor published his algorithm that can break RSA encryption codes. Since then, physicists, mathematicians, and engineers have been determining the ultimate capabilities for quantum computation and many quantum algorithms have been established as well. Quantum computation has now fundamentally altered our understanding of computation and complexity theory. Furthermore, it is inevitable that Moore's law will break down (in fact with the former chief architect at Intel recently suggesting that this will occur within a decade), and at this point quantum mechanical effects will be unavoidable. The idea of quantum computation is to harness these effects (rather than avoid them) in order to speed up computations for certain tasks. If you take this course, you will learn about the well known quantum algorithms for factoring integers and database search and in addition you will learn how quantum computation has altered our understanding of computation.

Course Outline:

Week 1: Course Overview, Turing Machines and Church–Turing Thesis
Week 2: Circuit Model of Computation, Cook–Levin Theorem on NP-Completeness
Week 3: Bounded Error Probabilistic Polynomial Time, Circuit Model of Quantum Computation
Week 4: Solovay–Kitaev Theorem, Bounded-Error Quantum Polynomial Time
Week 5: Deutsch–Jozsa and Simon’s Algorithm, Quantum Fourier Transform and Phase Estimation
Week 6: Error Estimates for Quantum Phase Estimation, Shor’s Quantum Order Finding Algorithm (Part I)
Week 7: Shor’s Quantum Order Finding Algorithm (Part II), Hidden Subgroup Problem
Week 8: Grover’s Algorithm, Amplitude Amplification
Week 9: Optimality of Grover’s Algorithm, Classical Simulation of Non-Entangling Circuits
Week 10: Quantum Merlin–Arthur (QMA), Error Reduction for QMA
Week 11: Local Hamiltonian Problem – QMA, QMA Hardness of Local Hamiltonian (Part I)
Week 12: QMA Hardness of Local Hamiltonian (Part II), Quantum Error Correction (Part I)
Week 13: Quantum Error Correction (Part II), Impossibility of Quantum Bit Commitment
Week 14: Quantum Communication Complexity, Final Presentations

Grading: There will be five assignments and a final presentation & report. The final presentation and report will serve as the final exam for the course.

Assignments 75%
Presentation and Final Report 25%.

LSU letter grades will be assigned according to the following table. Your end of semester numerical grades are rounded up to whole numbers (for example, 94.49 = 94, 94.50 = 95)
97-100% A+
94-97% A,
90-94% A−,
85-90% B+,
80-85% B,
75-80% B−,
70-75% C+,
65-70% C,
60-65% C−,
57-60% D+,
54-57% D,
50-54% D−,
less than 50%, F

Description of Activities that will be Graded:

Homework Assignments: Homework will be handwritten assignments, and the homework grade will be calculated as an average of the individual assignments. In more detail, students will be graded based on their performance on 5 challenging homework assignments, which often take anywhere between 5-10 hours to complete each. The homework assignments are given every 2-3 weeks and consist of 10-15 detailed problems to be worked out. The instructor grades the homework assignments. Each problem is graded as follows: two points for a complete solution, one point for some effort, and zero points for no attempt. Of course, there is some grey area: sometimes a 1.5 or 0.5 will be given as a score on a problem. The score for all problems on a homework assignment are added up and then translated to a score out of 100. Then all of the scores for the homework assignments are added and translated to a score out of 75 points, in a typical way.

Final project: Each student should find a recent research paper from the quantum computation literature and read it carefully. The goal is then to deliver a research-level presentation about the paper and prepare a final report that summarizes the contents of the research paper. It is also possible to pursue an original research topic for the final project. The paper or topic for the final presentation should be submitted for approval by the fifth week of class.

For the presentation: Each student should take no more than 15 minutes to present. This means no more than 8 slides in Powerpoint (not counting a title slide).

Adversarial review: During the presentations, each person should ask at least two questions at minimum of your peers. There will be 5 minutes for questions after each presentation.

For the report: Each student should turn in a final report. This consists of an introduction to the topic of the paper, a review of some of the technical details, what challenges needed to be overcome, and a summary of what are the open questions for future research. Five pages single-spaced is a reasonable minimum requirement for the report.

Expectations

LSU's general policy states that for each credit hour, you (the student) should plan to spend at least two hours working on course related activities outside of class. Since this course is for three credit hours, you should expect to spend a minimum of six hours outside of class each week working on assignments for this course. For more information see: http://catalog.lsu.edu/content.php?catoid=12&navoid=822.

LSU student code of conduct

The LSU student code of conduct explains student rights, excused absences, and what is expected of student behavior. Students are expected to understand this code as described here:
http://students.lsu.edu/saa/students/code. Any violations of the LSU student code will be duly reported to the Dean of Students.

Disabilities

Louisiana State University is committed to providing reasonable accommodations for all persons with disabilities. The syllabus is available in alternate formats upon request.

If you have a disability that may have some impact on your work in this class and for which you may require accommodations, please see a staff member in Disability Services so that such accommodations can be considered. Students that receive accommodation letters, please meet with me to discuss the provisions of those accommodations as soon as possible.

Academic Success

The primary ingredients of your academic success are attending class, managing your time efficiently, taking good notes, and developing good critical thinking and communication abilities. LSU has a number of excellent resources that will assist you in developing these skills. The place to begin is the Center for Academic Success (http://students.lsu.edu/academicsuccess). The CAS offers guidance on what learning strategies are best suited to your talents, tutoring in the basic subjects, and workshops on a variety of topics, from note taking to time management. Communication Across the Curriculum (http://cxc.lsu.edu) assist students in developing the communication skills necessary for academic and professional success. Finally, with respect to professional success, the LSU Olinde Career Center (http://students.lsu.edu/careercenter) can assist you in choosing a major and a profession that best suits your talents and passions and help you develop a career plan to ensure success when you graduate from LSU.