From:	noreply@wsu.edu
To:	curriculum.submit
Subject:	669920 New or Restore Course: PHYSICS 455/555
Date:	Friday, October 1, 2021 4:30:01 PM
Attachments:	2021.10.01.16.27.00.43.FormData.html 2021.10.01.16.26.59.39.currentFileUpload_Physics_555.pdf

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Matthew Duez has submitted a request for a major curricular change. His/her email address is: m.duez@wsu.edu.

Course Subject: PHYSICS

Course Number: 455/555

Title: Quantum Technologies and Computation

Lecture Hours: 3

Total Credits: 3

Prerequisite: none

Catalog Description: Fundamentals of quantum mechanics required for quantum computing and quantum information science; Technologies and platforms that enable quantum applications to computing, simulation, and advance sensing. Credit not granted for both PHYSICS 455 and PHYSICS 555

Grading Type: Letter graded A-F

Conjoint: Yes

Requested Effective Date: Fall 2022

Dean: Swindell, Samantha - Assoc Dean - CAS

Chair: Saam, Brian – Chair – Physics and Astronomy

UCORE Committee Approval Date	All-University Writing Com / Date

Catalog Subcommittee Approval Date	AAC, PHSC, or GSC Approval Date	Faculty Senate Approval Date

From: Saam, Brian
To: curriculum.submit
Cc: Swindell, Samantha; Stratton, Robin G
Subject: RE: 669920 New or Restore Course: PHYSICS 455/555
Date: Friday, October 1, 2021 4:30:56 PM

I approve this proposal in its current form.

Brian T. Saam, Ph.D.
Professor and Chair
Department of Physics and Astronomy
Washington State University
509-335-1182

From: curriculum.submit@wsu.edu <curriculum.submit@wsu.edu>
Sent: Friday, October 1, 2021 4:27 PM
To: Saam, Brian <brian.saam@wsu.edu>
Cc: Swindell, Samantha <sswindell@wsu.edu>
Subject: 669920 New or Restore Course: PHYSICS 455/555

Saam, Brian – Chair – Physics and Astronomy,

Swindell, Samantha - Assoc Dean - CAS,

Matthew Duez has submitted a request for a major curricular change.

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Conjoint: Yes

Requested Effective Date: Fall 2022

From: Swindell, Samantha
To: curriculum.submit; Saam, Brian
Subject: RE: 669920 New or Restore Course: PHYSICS 455/555
Date: Monday, October 4, 2021 11:25:59 AM

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1. I approve this proposal in its current form.

From: curriculum.submit@wsu.edu <curriculum.submit@wsu.edu>
Sent: Friday, October 1, 2021 4:27 PM
To: Saam, Brian <brian.saam@wsu.edu>
Cc: Swindell, Samantha <sswindell@wsu.edu>
Subject: 669920 New or Restore Course: PHYSICS 455/555

Saam, Brian – Chair – Physics and Astronomy,

Swindell, Samantha - Assoc Dean - CAS,

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Grading Type: Letter graded A-F

Conjoint: Yes

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Both Chair and Dean approval is required to complete the submission process. Please indicate that you have reviewed the proposal by highlighting one of the statements below and **reply all** to this email. (curriculum.submit@wsu.edu.)

Physics 455/555
Quantum Technologies and Computation

Justification

Quantum science is poised to revolutionize society, impacting everything from fundamental research, through consumer devices, to national security. The signing of the National Quantum Initiative Act in 2018 led the NSF to fund three Quantum Leap Challenge institutes so far and a variety of continuing programs in various subfields, and the DoE to fund five QIS Centers led by national laboratories in addition to ongoing funding opportunities. Similar funding opportunities have emerged in other agencies and foundations. This was only the first wave: The Senate recently passed bill S.1260 - United States Innovation and Competition Act of 2021 with bipartisan support directing $100 billion to bolster national competitiveness, transforming the NSF and research in this country. Quantum science will play a central role in this transformation as a significant motivator is competition with China which has now surpassed the US in terms of related quantum patents.

WSU has world leaders in quantum science, but currently lacks a significant presence in quantum computing. Physics 455/555 will be the first official course at WSU training students to become leaders in quantum computing. No comparable courses exist in the WSU catalog.

This course will be a cornerstone of WSU's Quantum Initiative to target the growing needs in industry and national labs for a quantum trained workforce. This fits well with WSU's land-grant mission, complementing quantum efforts in other parts of the state. (UW, for example, is more focused on specific research energies in quantum computing than on workforce training.)

Having a regular offering will help WSU attract both funding and students by demonstrating a commitment to this growing field.

While the goal of QC is the development of new computing paradigms far exceeding the capability of classical computers, the underlying principles are deeply founded in fundamental physics, and a physics background will be essential for realizing the potential gains. For this reason, the physics department is the natural home for this course.

Some of these foundations are currently taught through the core quantum physics courses Physics 450, and the graduate sequence Physics 550-552.

This new course complements these offerings by focusing on aspects of quantum physics directly related to quantum computation and related technologies, which are not currently part of the physics curriculum. In addition, it will be largely self-contained, relying only on a strong mathematical foundation of linear algebra. Thus, it will be accessible to upper-level students outside of the department, for example, from mathematics, chemistry, and electrical engineering and computer science. The attached sample Syllabus is based on a previous offering as Physics 590: special topics. This course was well attended, attracting participants from across WSU (physics, mathematics, and EECS), validating its feasibility and need.

In summary: WSU needs a quantum computing course as part of its Quantum Initiative to meet regional needs for a quantum train workforce, and to tap into significant new funding opportunities. We have the expertise to teach the course, and there will be significant interest from across WSU.

Response to Items from the Curriculum Handbook

1. There are no comparable courses offered anywhere at WSU.
2. This is a conversion of a topics course that was well attended.
3. The proposed course number is not currently in use, and fits within the x5x designation for quantum courses in the department.
4. This is not a UCORE course.
5. Please find attached the rational and syllabus.
6. Succinct catalog course description:

   Physics 455/555: **Quantum Technologies and Computation**: Fundamentals of quantum mechanics required for quantum computing and quantum information science; Technologies and platforms that enable quantum applications to computing, simulation, and advance sensing. Credit not granted for both PHYSICS 455 and PHYSICS 555. Offered at 400 and 500 level. Typically offered Fall.

Sample Syllabus

Course Information

Instructors: {{instructors}}
Course Assistants: {{assistants}}{{assistant_name}} {{assistant_email}}, {{assistant_office}}.
Office Hours: {{office_hours}}
Course Homepage: {{class_homepage}}
Class Number: {{class_number}}
Location and Time: MWF 12:10pm-1pm, Webster 947
Title: "PHYSICS 455/555: Quantum Technologies and Computation ({{class_term}}"
Recommended Preparation: Linear Algebra and Quantum Mechanics.
Grading: Grade based on assignments and project presentation.

Textbooks

- Nielsen and Chuang: "Quantum Computation and Quantum Information":
  ISBN: 9781107002173, EISBN: 9780511990809
  Principle textbook - available through the WSU Library (ProQuest).
- Preskill: Quantum Computation: (http://theory.caltech.edu/~preskill/ph229/)
  John Preskill's course at Caltech.

Student Learning Outcomes

Physics 455/555: By the end of this course, all students will:

1. Know the postulates of quantum mechanics and their consequences.
2. Be able to analyze quantum circuits.
3. Be familiar with the fundamental quantum algorithms.
4. Be familiar with current technologies being explored for realizing quantum computing.
5. Be aware of the potential advantages offered by quantum technologies, but cognizant of the physical challenges and limitations.
6. Be able to present a critical summary of a topic relevant to the class demonstrating awareness of the previous learning outcomes.

Physics 555: Graduate students will additionally:

7. Be able to review the literature about a specific topic relevant to the course that is under active investigate, and present a critical summary of this topic to the class considering the previous outcomes.

Expectations for Student Effort

Physics 455/555: For each hour of lecture equivalent, all students should expect to have a minimum of two hours of work outside class. All students are expected to keep up with the readings assigned in class, asking questions through the Perusall/Hypothes.is forums, and complete homework on time, and prepare their presentations.

Physics 555: Additionally, graduate students are expected to choose a topic that is being actively discussed in the literature, review this literature, and present about this topic.

Assessment and Grading Policy

Physics 455/555: Students will be assessed with assignments to ensure that the content-based learning outcomes 1 through 4 are realized. Learning outcomes 5 through 7 will be assessed through their presentations, which must compare and contrast the quantum technology/platform under consideration with other technologies and platforms. Assignments will be the same for both undergraduate and graduate students, and worth 20% of the final grade. Presentations will be worth the other 80% and will include an oral assessment of content covered in the assignments. The course will have no examinations.

Physics 455: Undergraduate presentations may be about any topic relevant to the course, subject to instructor approval. (Learning outcome 6)

Physics 555: Graduate presentations must be about an active research topic relevant to the course, subject to instructor approval, and must demonstrate a review of the appropriate literature relevant to this topic. (Learning outcome 7)

The final grade will be converted to a letter grade using the following scale:

Percentage P	**Grade**
$90.0\% \leq P$	A
$85.0\% \leq P < 90.0\%$	A-
$80.0\% \leq P < 85.0\%$	B+
$75.0\% \leq P < 80.0\%$	B
$70.0\% \leq P < 75.0\%$	B-
$65.0\% \leq P < 70.0\%$	C+
$60.0\% \leq P < 65.0\%$	C
$55.0\% \leq P < 60.0\%$	C-
$50.0\% \leq P < 55.0\%$	D+
$40.0\% \leq P < 50.0\%$	D
$P < 40.0\%$	F

Attendance and Make-up Policy

While there is no strict attendance policy, students are expected attend an participate in classroom activities and discussion. Students who miss class are expected to cover the missed material on their own, e.g. by borrowing their classmates notes, reviewing recorded lectures (if available), etc.

Course Timeline

Assignments will be given weekly and are due Fridays at 11:59pm

Linear Algebra: Shankar Chapter 1. Week 1

- Eigenvectors and Eigenvalues.
- Properties of Hermitian and Unitary matrices.
- Decompositions:
    - Spectral
    - Polar and SVD
    - Schmidt
- Tensor sums and products.

Quantum mechanics: Week 2

- Postulates
- Spin ½, Pauli matrices, Rotations.
- EPR pairs.
- Measurement
    - POV Measurements
    - von Neumann measurements (pointer states)
- Entanglement Measures
- Bell's Inequality.

Quantum Computing Theory Week 3

- No Cloning.
- Universal gates.
    - CNOT
    - Toffoli
- Communication.
    - Alice and Bob and Eve
    - Superdense coding
    - Teleportation.

Quantum Algorithms Week 4

- Grover, Deutsch
- Schor
- Adiabatic quantum computing.
- Quantum annealing.

Additional topics and presentations Weeks 5-13

1. Classical programming models and complexity
2. Quantum programming: Basic gates, and programming models (universal computing).
3. Quantum Algorithms
4. Ion Trapping
5. Quantum Error Correction: Ancillary qubits.
6. Quantum Complexity: What can be done with quantum computers that cannot be done with classical computers (presumably and provably).
7. Communication: Encryption protocols.
8. Quantum Optics: Experimental quantum communication.
9. Neutral atoms in lattices and optical tweezers
10. Atom interferometry
11. Entanglement purification/Producing ground states.
12. Superconducting qubits
13. NV centers
14. MRI quantum computing
15. Quantum Simulation

Thanksgiving Break – No Class *Week 14*

Quantum Computing and Presentations Weeks 15-16

- Running quantum algorithms on quantum hardware.
- Student presentations.

Presentation Topics

- Presentations should be 30-40 minutes to leave time for discussion.
- Please create a folder for your topic in "Notes and Discussions", and upload any slides, notes, or other relevant material for your topic.
- Please create a Notes document in your folder with the following:
    - **Introduction**: Please provide a summary of the topic.
    - **References**: Include any helpful references.
    - **Questions**: Please curate questions and discussions in this section. Use this section to ask any questions you have while working on your material, and then to help answer classmate questions. This should be a dynamic section where all members of the course participate.

Other Information

COVID-19 Statement

Per the proclamation of Governor Inslee on August 18, 2021, masks that cover both the nose and mouth must be worn by all people over the age of five while indoors in public spaces. This includes all WSU owned and operated facilities. The state-wide mask mandate goes into effect on Monday, August 23, 2021, and will be effective until further notice.

Public health directives may be adjusted throughout the year to respond to the evolving COVID-19 pandemic. Directives may include, but are not limited to, compliance with WSU's COVID-19 vaccination policy, wearing a cloth face covering, physically distancing, and sanitizing common-use spaces. All current COVID-19 related university policies and public health directives are located at https://wsu.edu/covid-19/. Students who choose not to comply with these directives may be required to leave the classroom; in egregious or repetitive cases, student noncompliance may be referred to the Center for Community Standards for action under the Standards of Conduct for Students.

Academic Integrity Statement

Academic integrity is the cornerstone of higher education. As such, all members of the university community share responsibility for maintaining and promoting the principles of integrity in all activities, including academic integrity and honest scholarship. Academic integrity will be strongly enforced in this course. Students who violate WSU's Academic Integrity Policy (identified in Washington Administrative Code (WAC) 504-26-010(4) will fail the course, will not have the option to withdraw from the course pending an appeal, and will be reported to the Center for Community Standards.

Cheating includes, but is not limited to, plagiarism and unauthorized collaboration as defined in the Standards of Conduct for Students, WAC 504-26-010(3). You need to read and understand all of the definitions of cheating. If you have any questions about what is and is not allowed in this course, you should ask course instructors before proceeding.

If you wish to appeal a faculty member's decision relating to academic integrity, please use the form available at community standards.wsu.edu. Make sure you submit your appeal within 21 calendar days of the faculty member's decision.

Severe Weather Policy

For severe weather alerts, see: http://alert.wsu.edu/ and https://oem.wsu.edu/emergency-procedures/severe-weather/. In the event of severe weather affecting university operations, guidance will be issued through the alert system.

Students with Disabilities

Students with Disabilities: Reasonable accommodations are available for students with documented disabilities or chronic medical conditions. If you have a disability and need accommodations to fully participate in this class, please visit your campus Access Center website (websites listed below) to follow published procedures to request accommodations. Students may also call or email the Access Center to schedule an appointment with an Access Advisor. All disability related accommodations are to be approved through the Access Center. It is a university expectation that students with approved accommodations visit with instructors (in person or via Zoom) within two weeks of requesting their accommodations to discuss logistics.

For more information contact a Disability Specialist on your home campus:

- Pullman, WSU Global Campus, Everett, Bremerton, and Puyallup: 509-335-3417 Access Center (https://www.accesscenter.wsu.edu) or email at access.center@wsu.edu
- Spokane: 509-358-7816 Access Services (https://spokane.wsu.edu/studentaffairs/access-resources/) or email j.schneider@wsu.edu
- Tri-Cities: Access Services (http://www.tricity.wsu.edu/disability/) or email g.hormel@wsu.edu
- Vancouver: 360-546-9238 Access Center (https://studentaffairs.vancouver.wsu.edu/student-wellness-center/access-center) or email van.access.center@wsu.edu

Accommodation for Religious Observances or Activities

Washington State University reasonably accommodates absences allowing for students to take holidays for reasons of faith or conscience or organized activities conducted under the auspices of a religious denomination, church, or religious organization. Reasonable accommodation requires the student to coordinate with the instructor on scheduling examinations or other activities necessary for course completion. Students requesting accommodation must provide written notification within the first two weeks of the beginning of the course and include specific dates for absences. Approved accommodations for absences will not adversely impact student grades. Absence from classes or examinations for religious reasons does not relieve students from responsibility for any part of the course work required during the period of absence. Students who feel they have been treated unfairly in terms of this accommodation may refer to Academic Regulation 104 – Academic Complaint Procedures.

Safety and Emergency Notification

Classroom and campus safety are of paramount importance at Washington State University, and are the shared responsibility of the entire campus population. WSU urges students to follow the "Alert, Assess, Act," protocol for all types of emergencies and the "Run, Hide, Fight" response for an active shooter incident. Remain ALERT (through direct observation or emergency notification), ASSESS your specific situation, and ACT in the most appropriate way to assure your own safety (and the safety of others if you are able).

Please sign up for emergency alerts on your account at MyWSU. For more information on this subject, campus safety, and related topics, please view the FBI's Run, Hide, Fight video and visit the WSU safety portal.

Full details can be found at https://provost.wsu.edu/classroom-safety/

Discrimination and Harassment Policy Statement

Discrimination, including discriminatory harassment, sexual harassment, and sexual misconduct (including stalking, intimate partner violence, and sexual violence) is prohibited at WSU (See WSU Policy Prohibiting Discrimination and Harassment (Executive Policy 15) and Standards of Conduct for Students (WAC Code 504-26)).

If you feel you have experienced or have witnessed discriminatory conduct, you can contact the WSU Office of Civil Rights Compliance & Investigation (CRCI) and/or the WSU Title IX Coordinator (see crciwsu.edu/title-ix/) at 509-335-8288 to discuss resources, including confidential resources, and reporting options. (Visit crci.wsu.edu for more information).

Most WSU employees, including faculty, who have information regarding sexual harassment or sexual misconduct are required to report the information to CRCI or a designated Title IX Coordinator or Liaison. Visit https://ccr.wsu.edu/file-a- complaint/ for more information.

Students in Crisis - Pullman Resources

If you or someone you know is in immediate danger, DIAL 911 FIRST!

- Student Care Network: https://studentcare.wsu.edu/
- Cougar Transit: 978 267-7233
- WSU Counseling and Psychological Services (CAPS): 509 335-2159
- Suicide Prevention Hotline: 800 273-8255
- Crisis Text Line: Text HOME to 741741
- WSU Police: 509 335-8548
- Pullman Police (Non-Emergency): 509 332-2521
- WSU Office of Civil Rights Compliance & Investigation: 509 335-8288
- Alternatives to Violence on the Palouse: 877 334-2887
- Pullman 24-Hour Crisis Line: 509 334-1133