New Graduate Program (Majors, Sequences, Certificates) Proposal
Illinois State University - Graduate Curriculum Committee

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Title of New Program Master of Science in Physics

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Proposed Starting Catalog Year 2024-2025

Associated Course Proposal(s):
New Graduate Course proposal PHY 407 titled *PHY 407 Seminar in Physics*
New Graduate Course proposal PHY 417 titled *PHY 417 Mathematical Methods*
New Graduate Course proposal PHY 420 titled *PHY 420 Classical Mechanics*
New Graduate Course proposal PHY 425 titled *PHY 425 Statistical Mechanics*
New Graduate Course proposal PHY 440 titled *PHY 440 Advanced Electricity & Magnetism*
New Graduate Course proposal PHY 455 titled *PHY 455: Solid State Physics*
New Graduate Course proposal PHY 461 titled *PHY 461 General Relativity*
New Graduate Course proposal PHY 462 titled *PHY 462: Astrophysics*
New Graduate Course proposal PHY 470 titled *PHY 470 Advanced Experimental Physics*
New Graduate Course proposal PHY 473 titled *PHY 473 Space and Plasma Physics*
New Graduate Course proposal PHY 484 titled *PHY 484: Advanced Quantum Mechanics*
New Graduate Course proposal PHY 488 titled *PHY 488: Advanced Computational Physics*
New Graduate Course proposal PHY 490 titled *PHY 490 Research Development in Physics*
New Graduate Course proposal PHY 499 titled *PHY 499 Independent Research in Physics*

1. Proposed Action

✓ New Major
New Sequence
New Certificate
More than 50% of courses in this program are Distance Education

Degree Type(s)

Master of Science

2. Provide *Graduate Catalog* copy for new program.

The Master of Science (MS) in Physics is designed to offer a well-rounded education that would open doors to interesting, well-paying careers in industry, government, higher education, and non-profits.

For the MS in Physics, students are required to complete a total of 30 credit hours –

- 14-credit core courses: PHY 417, PHY 425, PHY 440, PHY 484
- 6-credit electives: Two courses out of PHY 420, PHY 455, PHY 461, PHY 470, PHY 471, PHY 473, PHY 480, PHY 488
- 4-credit research development and seminar: PHY 490, PHY 407
- 6-credit thesis: PHY 499

For the research development/thesis students are assigned a research advisor, and the students work closely with the adviser to complete a thesis based on original research. Upon completion of a written thesis, a final oral examination/thesis defense is required. A range of research projects in the areas of nanotechnology, electronic and photonic materials, quantum materials, biophysics, laser physics, quantum field theory, astrophysics, etc., are being offered.

In general, students admitted to the MS in Physics program should have completed coursework in science and math equivalent to that required for a B.S. degree in Physics, Electrical Engineering, or Material Science & Engineering or equivalent.

3. Provide a description for the proposed program.

Overview of the department: The physics department currently offers a BS in five separate degree sequences within the major. Despite the physics department being one of the smaller departments at ISU, according to three-year average for Classes of 2016 through 2018 from the American Institute of Physics (AIP), ISU Physics is ranked one of the largest Bachelor's-only physics department nationwide. ISU physics has a long history of involving undergraduates in research. In last five years, the department faculty members and students have published more than 70 peer reviewed articles in reputed journals and made more than 100 presentations. The undergraduates from ISU physics have gone on to enroll in graduate programs in prestigious public and private universities, as well as secured jobs in private sectors. Moreover, ISU physics has an exceptional track record of securing external funding. About 50% of our current faculty has active external grants, both federal and private, with a total amount of ~ $2M secured in the last five years.

Brief Description of the Curriculum: The proposed MS program will build on the success of our department and its mentorship of undergraduates by offering opportunities for education and research to graduate students and contribute to a "Thriving Illinois". As ISU becomes a more comprehensive university that includes engineering and other STEM disciplines, physics has the opportunity to grow into a department that not only supports these efforts but thrives because of them.

Nationwide, the most successful MS programs in physics in the nation, have the following aspects:

- A minimum of 30 credit hours is required to graduate with a MS degree in physics
- 4-5 traditional graduate only physics courses make up a core curriculum
- Rather than "tracks", electives provide an opportunity for students to specialize
- Students are required to complete a research thesis toward fulfillment of the degree

Our MS in physics would require the following:

14 hours of core coursework: PHY 417, PHY 425, PHY 440, PHY 484

6 hours of graduate electives

4 hours of research development and seminar: PHY 490 (2 hours), PHY 407 (2 hours)

6 hours of thesis: PHY 499

In addition to four core courses, the program will offer four graduate electives every year. Students will have the option of choosing two out of the four electives for graduation. Students need to complete two hours of research development in the first year, and six hours of thesis work in their final year.

By offering a variety of electives, students will have the opportunity to tailor their degree sequence to their own research interests. A plan of study for the proposed MS program is discussed below.

Tentative Plan of Study for the MS program: Students need 30 total credit hours (14 graduate only core courses, 6 electives, 8 from research related courses and 2 from research seminar). A tentative plan of study of the MS program is given below.

Fall Year 1
Core: PHY 417 Math Methods (3)
Core: PHY 440 Electricity & Magnetism (4)

PHY 407 Graduate Seminar in Physics (1)

PHY 490 Research Development in Physics (1)

Spring Year 1
Core: PHY 484 Quantum Mechanics (4)
Core: PHY 425 Statistical Mechanics (3)

PHY 407 Graduate Seminar in Physics (1)

PHY 490 Research Development in Physics (1)

Fall Year 2
Elective-1 (3)

PHY 499 Independent Research in Physics (3)

Spring Year 2

Elective-2 (3)

PHY 499 Independent Research in Physics (3)

Core Courses: The core graduate courses – PHY 417, PHY 440, PHY484, PHY 425 will be developed from scratch, and will be offered every year.

Graduate Electives: We will periodically offer the following graduate level elective courses: PHY 470 Advanced Experimental Physics (3); PHY 488 Computational Physics (3); PHY 420 Classical Mechanics (3); PHY 462 Astrophysics (3); PHY 471 Biophysics of Neurological Systems (3); PHY 455 Solid State Physics (3); PHY 461 General Relativity (3); PHY 473 Space and Plasma Physics (3). Every year, four out of these eight elective courses will be offered. As mentioned earlier, students will have the option of choosing two out four electives that will be offered each year for graduation. These 400 level electives will be offered along with their existing 300 level undergraduate counterparts with additional requirements for the graduate level courses. The 400 level courses will cover significantly more material than a purely undergraduate 300 level course and deliver an appropriate graduate-level curriculum.

Graduate Seminar: In addition to attending the weekly department seminar, the students will actively analyze, construct/create, and evaluate information presented in technical and/or scientific journals. The students will examine best practices and implement them for designing, developing and presenting a quality scientific presentation using a presentation software such as PowerPoint, LaTex, MS-word etc. The students will also present results from their own research, and practice critical evaluation of other students' work. The Graduate Seminar in Physics will be offered along with its undergraduate counterpart, PHY 307: Seminar in Physics.

Research Development in Physics: After a student is admitted to the MS Physics program, the student will be assigned a Faculty Advisor. The students will work with their assigned Faculty Advisor to learn the nuts and bolts of how to conduct original research that include identifying a research project, gaining skills (experimental or computational) that are required to carry out the research project, etc. After completion of the of the Research Development, the students will submit a "Thesis proposal" for it to be approved by the Graduate Committee.

Independent Research in Physics: In "Independent Research in Physics", the students will work with their Faculty Advisors to complete individual research projects. The goals of this course is to provide an independent research experience for the students; teach the students how to write a manuscript that include producing figures, figure captions, table of contents, tables, references, introduction, abstract, etc, and complete a Thesis.

4. Provide a rationale of proposed program.

Growth of STEM discipline at ISU

Having an MS program in Physics will contribute to the growth of the Physics Department; thereby directly contributing to the growth of STEM disciplines as ISU becomes a more comprehensive university that includes engineering and other disciplines. The Graduate Teaching Assistants (GTAs) hired through the MS program in Physics will cover labs and discussion sections in the Physics courses (PHY 110,111, and 112) associated with the Engineering programs. Therefore, the success of the MS program in physics is critical to the success of the Engineering program.

Moreover, we anticipate the total amount of funding, and thereby the associated indirect cost (IDC) earnings from NSF alone for physics to increase by more than 60% with the establishment of the MS program. To be more specific, as per the NSF website, ISU currently has 26 active research NSF grants; out of these 26 active grants, 6 grants are from physics. Therefore, despite being one of the smallest departments, Physics accounts for approximately 23% of all NSF grants at ISU. The total amount associated with these 5 NSF grants is ~ $1.2M and that is without any participation of graduate student. Hypothetically, if we requested funding for two graduate students for each of these five grants, the total amount of these grants would be ~ $2M (the stipend is calculated based on 0.5 FTE, $1300 per month), which is an increase of 62.5% funding from NSF only for physics.

In addition, for many of the research grants, such as NSF CAREER, DOE, etc. there is a floor mount of $500,000 to even apply for these grants. Without requesting funds for graduate students (and postdocs), it is almost impossible to justify the floor amount. Therefore, we would be able to apply for other funding with larger floor amounts.

Increased enrollment of ISU physics department

It is well documented that a physics master's degree opens doors to interesting, well-paying careers in industry, government, education, and not-for-profit sectors. For example, see the following physics today article, https://physicstoday.scitation.org/doi/10.1063/PT.3.4180. Over the past few years, the enrollment of some of the largest MS physics degree conferring departments in the country with 15–20 a year have increased by 4-5 times, up from just 3–5 annually a decade or so ago(See attached list of Physics MS programs nationwide). There are currently only 53 programs in the US where the MS degree is the highest degree awarded by the physics department. Only two of these (DePaul and Western Illinois) are in the state. We believe that with current demand, we would be able to attain an enrollment of 15 - 20 students within the first few years. This would correspond to about 2 grad students per faculty member for research theses. If the program proves to be very popular, we would certainly be open to expanding it. This would then require more resources that include faculty, staff, space, etc.

Broaden STEM Workforce and fulfil employer demand

The data from the AIP report on Physics MS students indicates that the vast majority are either employed (39%) or are enrolled in a PhD program (47%) within one year after their degree (6% unemployed, and 8% left the country) (see attached AIP Job statistics document). Furthermore, the median starting salary for private sector positions was $70,000 (in 2019). This tends indicate a healthy market demand for the graduates. It should be noted that in the report, exiting masters are people who received their degrees from a US physics department and left that department with no degree higher than a master's degree.

The market PULSECHECK states that "in the six-state region and in Chicago, employer demand for master's-level physics professionals is slightly increasing. Specifically, three of the common master's-level physics occupations project significant employment growth: software developers and programmers, computer and information research scientists, and market research analysts and marketing specialists. However, the six-state region and Chicago's reported degree completions suggest consistent enrollments in master's-level physics programs, despite growing employer demand. While analysis does not yet support or discourage program development, data reveal high demand for programming language skills from master's-level physics graduates. If master's-level physics program development continues, research suggests an emphasis on computer programming languages."

The BS physics program at ISU has a long history and tradition in computational physics education. The department received an award from the Department of Energy (DOE) as one of the first undergraduate programs in computational physics in the nation. Eight of current faculty members are involved in computational physics research. As part of their research, the faculty members routinely use modern programming language (such as python), deal with large amount of data, work with external collaborators in national labs and universities to access in supercomputer facilities and develop software packages. Therefore, ISU physics is very well positioned to train master's- level physics graduates with skills related to data science, software development, programming language, etc.

The PULSECHECK did not include an analysis of related fields where many physics graduates are employed, for example optics & photonics, nanotechnology, material physics, etc.

Optics & photonics is a fast-growing industry due to the increased use of optics and photonics technology in our daily lives, for example, from smart phones to laser eye surgery. Surprisingly, the biggest optics/photonics programs in the US and Europe consist of a total of only 200–300 graduate students. A quick search with "optical engineer/scientist" at indeed.com resulted in more than 1,000 jobs available at this time. This clearly shows there are not enough students trained in the field of optics and photonics. Three of the current faculty (Drs. Grobe, Manna, Su) are involved in optics and photonics related research. These faculty have outstanding record of performing world-class research and attracting federal funding.

Nanotechnology is integral part of our lives and growing faster than ever due to the advancement of technologies, and the benefit of nanotechnology extends from medical, ethical, mental, legal and environmental applications to fields such as engineering, biology, chemistry, computing, materials science, and communications. A quick search with "nanotechnology" at indeed.com resulted ~ 1,000 jobs available at this time. Four of the current faculty (Drs. Biswas, Bergfield, Manna, Marx) are involved in nanotechnology and material physics related research. Recently, physics has acquired a state-of-the-art multi-user Field Emission Scanning Electron Microscope (FESEM) equipped with secondary electron (SE), backscatter electron (BSE), and cathodoluminescence (CL) imaging, and energy dispersive x-ray spectroscopy (EDS). This multi-user facility would expand cutting-edge nanotechnology related research in the department.

Therefore, our MS program will provide an ideal platform for students to be trained in optics and photonics skills, nanotechnology, material science, etc, as well and broaden the STEM workforce

Impact of the MS program – Contributing to "A Thriving Illinois"
Our MS program will contribute to the Illinois Board of Higher Education's (IBHE) mission of creating and sustaining a world-class educational system in Illinois that will contribute to a "Thriving Illinois". Our program will help develop an inclusive economy and broad prosperity with equitable paths to opportunity for all, especially those facing the greatest barriers, and thereby provide higher education paths to Equity, Sustainability, and Growth as outlined below.

Equity – We note that Illinois' population is becoming more and more diverse, and the labor market increasingly demands post-high school education and ongoing training for all but entry-level jobs. We need broad paths and specific strategies to progress for all regardless of race, ethnicity, class, gender, geography, or age—for high school graduates and adult learners—so all can contribute to and benefit from economic growth. Amongst the 10 universities in central Illinois (Bradley, Eastern Illinois, ISU, Illinois Wesleyan, Lincoln Christian, Millikin, Quincy, University of Illinois Springfield, University of Illinois Urbana-Champaign, Western Illinois University (WIU), only Western Illinois has a MS-only granting physics department. While WIU MS program continues to grow and thrive, several students travel out of state to pursue MS degree in physics resulting in loss of valuable intellectual and economic capital in those students. The MS Physics program at ISU will make higher education more accessible, and thereby create new pathways students for all regardless of race, ethnicity, class, gender, geography, or age and contribute to economic growth

Sustainability – We recognize the necessity to create educational paths that are financially sustainable for students and for higher education institutions to meet the vision of a thriving Illinois. Our financial model is based on offering graduate/teaching assistantships for approximately half of the enrolled students. Moreover, as mentioned above, ISU physics has an exceptional track record of securing external funding (both federal and private), with a total amount ~ $2M secured in the last five years. Often this amount is limited by the fact that we don't offer any graduate options. Therefore, we would be able to offer research assistantship to the enrolled students. Thereby, our program will be affordable for students and families, and create a financially sustainable education system for the future.

Growth – We understand that Illinois cannot thrive without a future-ready workforce plus the institutional research and innovation that are crucial to driving economic growth. Upon completion of their degrees, the students are expected join the STEM work in various areas that include but not limited to data analytics, energy materials and technology in industries (such as State Farm, Country Financial, Caterpillar, Rivian, etc.) in Illinois as well as join top-class PhD programs in the nation. If successful, our program may also grow to encompass a

PhD option. Moreover, our MS program is expected to attract international students, which will enhance the talent pool, and thereby contribute to economic growth. Therefore, our effort will contribute towards a strong, nimble, and innovative higher education system, including career education, inclusive talent development, innovation and job creation for tomorrow.

Contribute to Equity, Diversity, and Inclusion (EDI)

Upon establishment of the MS program in Physics, the physics department will create a Graduate Student Diversity Committee that will contribute to graduate student-driven initiatives that support equity, diversity, and inclusion in the community. For example,

APS Inclusion, Diversity, and Equity Alliance –The APS-IDEA (American Physical Society- Inclusion, Diversity, and Equity Alliance) is a new initiative with a mission of empowering and supporting physics departments, laboratories, and other organizations to identify and enact strategies for improving equity, diversity, and inclusion (EDI). Our department will join the APS Inclusion, Diversity, and Equity Alliance (APS-IDEA) program to enhance EDI related efforts.

Grad-Influencers Program – The Graduate Student Diversity Committee would create a graduate student organized initiative aimed at fostering graduate connections within the department by pairing incoming students with upper year students who are experienced in navigating academic and personal issues. Under this program, incoming students will be paired with a compatible upper-year student (via a short survey) and then will be encouraged to interact throughout the year. Each student will get access to the resources and network of their mentor that can answer questions about the department or campus life. Each mentor will receive training from the Health Promotion and Wellness office at ISU, to learn best practices for helping their mentee with any personal issues they may face.

Outreach, Education, and Collaborative Program – ISU Physics currently offers a variety of outreach services including Physics on the Road outreach program which includes taking demonstrations into K-12 classrooms, science centers, museums, etc. The graduate student diversity committee will participate in these activities for improving equity, diversity, and inclusion within the community. In addition, the graduate student diversity committee will coordinate with STEM Alliance Program, Women in Physics group, Charles Morris STEM social program, ISU Noyce Scholarship, and NexSTEM programs to make connections between students and research labs and play a critical role in encouraging unrepresentative minority students in choosing and continuing STEM career.

5. Describe the expected effects of the proposed program on existing campus programs (if applicable).

As detailed in the “approved” financial implication form (FIF), we have requested funding for 10 gradate teaching assistants (GTAs). The primary use of GTAs will be in covering labs and discussion sections in the Physics for Scientists and Engineers Courses (PHY 110,111, and 112). Once the Engineering School is operational, all the general, mechanical and electrical engineering students will be required to take all three courses in the sequence. Assuming there are 150 engineering students enrolled per year, even if we are able to balance the load, it would have 75 engineering students in each of the three classes every semester. We currently enroll approximately 60 students per semester in PHY 110, 25 students in PHY 111 and 10 students in PHY 112. This gives a ballpark figure of 135 students in PHY 110, 100 students in PHY 111 and 85 students in PHY 112 when the engineering program is fully operational. For the calculus-based course, traditionally, the professor teaches the large lecture sections and the break the class out into sections of 25-35 students for discissions that are led by GTAs. In addition to the discussion sections, we need to have lab sections. These are capped at 24 students per lab so we will need instructors for 5/6 labs for PHY 110, 4/5 labs for PHY 111 and 3/4 labs for PHY 112 for a total of 12-15 lab sections. A traditional load for a GTA in physics programs is leading one lab section and one discussion section, as well as holding 3-4 office hours per week. With these numbers, we would require 10-12 GTAs for covering the Physics for Scientists and Engineers sections alone. Therefore, for the Engineering programs to succeed, it is critical that the MS Physics program is up and running.

6. Describe the expected curricular changes required, including new courses. If proposals for new courses that will be or have been submitted, please reference those related proposals here:

As discussed above, students need 30 total credit hours (14 graduate only core courses, 6 electives, 8 from research and 2 from seminar). For the MS program in Physics, we will be submitting the following new course proposals soon.

PHY 407 Graduate Seminar in Physics (2); PHY 417 Math Methods (3); PHY 425 Statistical Mechanics (3); PHY 440 Electricity & Magnetism (4); PHY 484 Quantum Mechanics (4); PHY 420 Classical Mechanics (3); PHY 455 Solid State Physics (3); PHY 461 General Relativity (3); PHY 473 Space and Plasma Physics (3); PHY 462 Astrophysics (3); PHY 470 Advanced Experimental Physics (3); PHY 488 Computational Physics (3); PHY 490 Research Development in Physics (2); PHY 499 Independent Research in Physics (6);

Note that PHY 471: Biophysics of Neurological Systems has already been approved for Graduate Credit.

7. Anticipated funding needs and source of funds.

Please see the attached “approved” financial implication form. Here we briefly describe anticipated funding needs. Operating Expenses – We requested $40,000 for Operating Expenses in year 1 and subsequently $5,000 per year. We will need funds for purchasing new experimental setups for graduate labs as well as computational facilities for running simulations. On average, one new experiment costs approximately $10,000. The $40000 will be used for purchasing three new experiments and purchasing computers. The $5000 in future years will be used to purchase consumable supplies and maintaining software licenses. AEF would be appropriate funds for this. Personnel – We will begin the program with existing T/TT faculty. We requested funding for a new faculty member once we have 10 students enrolled in the program, most likely in the second year of the program. We also requested funding for 10 GTAs. The GTAs are currently paid at the rate of $1300 per month for 9 months (approximately 0.5 FTE, 20 hours/week). Therefore, the GTA would cost approximately $117,000 per year. Facilities - Office space for graduate students has been identified and evaluated by Facilities, but the room needs to be renovated to make it usable. The department needs additional funds to renovate space for graduate student offices (space has been identified and cleared out. An estimate has been obtained from Facilities for constructing a wall to separate the space.) We are requesting $25000 to renovate MLT 207 for graduate student offices.

8. No Does this program count for teacher education?

9. The following questions must be answered.

Yes Have you confirmed that Milner Library has sufficient resources for the proposed program?

N.A. Have letter(s) of concurrence from affected departments/schools been obtained?
A departments/school is affected if it has a program with significant overlap or if it teaches a required or elective course in the program.