The University Senate of Michigan Technological University
Proposal 63-21

A New Graduate Certificate: Advanced Computational Physics

Submitted by: Department of Physics
Co-sponsored by: Department of Computer Science

1. **Version Date: March 29, 2021**

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3. **Interdisciplinary Program:** Approval from the collaborating department and college was obtained in the Deans' Council before forwarding to the Provost's office and the senate. Advising and administrative duties will be housed entirely in the Physics department.

4. **General Description and Characteristics**
This 9-credit Graduate Certificate in "**Advanced Computational Physics**" includes the following objectives:

   a) Attract graduate students to our graduate programs who are interested in Computational Physics to solve interdisciplinary problems.
   b) Provide a broad spectrum of computational techniques in science and engineering to graduate students.
   c) Enhance the credibility and marketability of the graduate students with practical skills and intellectual backgrounds needed for their career in the future.

   Catalog Description: The graduate certificate in "**Advanced Computational Physics**" develops a foundation of programming, UNIX computing environment, system libraries, and computer graphics, to enable students to start exploring more advanced computational topics. Students (1) learn basic and advanced numerical algorithms, (2) develop and implement numerical methods and computer simulations using these elements of new skills, tools, and knowledge, and (3) explore the application of advanced computation to scientific problems in their research areas.

   Graduate Learning Outcome (GLO) Assessment

   GLO 1: Upon completion of the certificate, students will be able to develop or augment advanced computational techniques and perform physics simulations in a high-performance computing environment.

   GLO 2: Students receiving this certificate will be able to check and analyze the computational physics results and interpret data using the advanced methods taught.

5. **Title of Program:** "Graduate Certificate in Advanced Computational Physics"

6. **Rationale**

Numerical programming and computer simulations are now ubiquitous throughout any subject in physics. Thus, computational physics has grown to be an appealing field to graduate students who wish to acquire advanced and modern skills to solve interdisciplinary problems. The certificate in Advanced Computational Physics will provide them with recognition for their extra efforts and hence will increase the market value of the students.

7. **Discussion of Related Programs**

Our proposed certificate is unique in its requirement and incorporation of physics-focused, computational courses related to various interdisciplinarity subjects. Several other universities offer similar certificate programs regarding more general practice in scientific computations. These examples include the following universities:

Texas A&M University (https://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/science/interdepartmental/computational-sciences-certificate/)

University of Maryland (https://amsc.umd.edu/academics/program-concentrations/scientific-computation.html?id=74)

University at Buffalo (https://grad.buffalo.edu/programs/computational-science-ac.html)

From the information in these links, there is no evidence that these external programs are being offered online.

8. **Projected Enrollments**

Table 1 shows the estimated minimum targets on the assumption that more aggressive marketing strategies will be deployed. The enrollment cap depends on the number of sections that can be allocated to each course. The certificate can be offered online in the future when the online version of the required and elective courses becomes available.

Table 1. Estimated minimum enrollment by year.

Academic Year	On Campus
2021-2022	2
2022-2023	2
2023-2024	3
2024-2025	3
2025-2026	4

9. **Curriculum Design**

This 9-credit certificate consists of two required courses, and one elective course. A maximum of three credits may be at the 4000 level. The required and elective course list, along with the course descriptions, are given below. It is expected that students will work with the program advisor to select courses that fit their interests and prerequisite skills.

Required Course - 6 credits
PH 4390 Computational Methods in Physics (3 credits)
PH 5395 Computer Simulation in Physics (3 credits)

Elective Courses - at least 3 credits
CS/EE 5841 Machine Learning (3 credits)
UN 5390 Scientific Computing (3 credits)
CS/EE 5821 Computational Intelligence - Theory and Application (3 credits)
MA 5761 Computational Statistics (3 credits)
CS 5491 Cloud Computing (3 credits)
PH 5396 – Statistics, Data Mining and Machine Learning in Astronomy (3 credits)

Course Descriptions
PH 4390 - *Computational Methods in Physics*
An overview of numerical and computer methods to analyze and visualize physics problems in mechanics, electromagnetism, and quantum mechanics. Utility and potential pitfalls of these methods, basic concepts of programming, UNIX computing environment, system libraries, and computer graphics are included.

PH5395 - *Computer Simulation in Physics*
Computational research is an integral part in physics, materials science, and engineering.
This course is geared for advanced undergraduate students and graduate students interested to work in research fields such as condensed matter physics, astrophysics, biophysics, atmospheric physics, chemical engineering, mechanical engineering, electrical engineering, and other related fields.

CS/EE 5841 - *Machine Learning*
This course will explore the foundational techniques of machine learning. Topics are pulled from the areas of unsupervised and supervised learning. Specific methods covered include naive Bayes, decision trees, support vector machine (SVMs), ensemble, and clustering methods.

UN 5390 - *Scientific Computing*
Set in a Linux environment, the course offers exposure to Foss tools for developing computational and visualization workflows. Students will learn to translate problems into programs, understand sources of errors, and debug, improve the performance of and parallelize the code.

CS/EE 5821 - *Computational Intelligence - Theory and Application*
This course covers the four main paradigms of Computational Intelligence, viz., fuzzy systems, artificial neural networks, evolutionary computing, and swarm intelligence, and

their integration to develop hybrid systems. Applications of Computational Intelligence include classification, regression, clustering, controls, robotics, etc.

MA 5761 - *Computational Statistics*
Introduction to computationally intensive statistical methods. Topics include resampling methods, Montes Carlo simulation methods, smoothing technique to estimate functions, and methods to explore data structure. This course will use the statistical software S-plus.

CS 5491 - *Cloud Computing*
Overview of the principles, methods, and leading technologies of cloud computing. Topics include cloud computing concepts: Hadoop, MapReduce; Software as a Service (SaaS); Platform as a Service (PaaS); Infrastructure as a Service (IaaS); workload patterns and resource management; migrating to the cloud; and case studies. Students will build their own cloud application using Amazon or IBM cloud services.

PH 5396 - Statistics, Data Mining and Machine Learning in Astronomy
The course focuses on modern problem-solving in Astronomy and Astrophysics through statistical inference, machine learning algorithms, and data mining techniques. Students will be presented with data sets and research problems in astrophysics and will learn how to formulate solutions.

10. New Course Descriptions

PH5395 - *Computer Simulation in Physics*
Computational research is an integral part of physics, materials science, and engineering.
This course is geared for advanced undergraduate students and graduate students interested to work in research fields such as condensed matter physics, astrophysics, biophysics, atmospheric physics, chemical engineering, mechanical engineering, electrical engineering, and other related fields.

11. Model Schedule Demonstrating Completion Time

The minimum completion time is two semesters. A typical schedule is shown below.

Fall Semester	***Spring Semester***
PH 4390 Computational Methods in Physics	PH 5395 Computer Simulation in Physics
Elective (if not in fall, then in spring)	Elective (if not in fall, then in spring)

12. Library and Other Learning Resources

No additional library or other learning resources are required.

13. Description of available/needed equipment

No additional equipment is needed.

14. Program Costs

No additional program costs are anticipated.

15. **Accreditation Requirements**
None

16. **Planned Implementation Date**
This program has an anticipated start in Fall 2021. The certificate program will be extended into an online program as soon as it is established and practical to do so.

Additional Information for New Programs:

1. **Program-Specific Policies, Regulations and Rules.**
This program will follow Senate Policy 411.1 for Graduate Certificates. No additional program-specific polices apply beside the curricular requirements described above.

2. **Scheduling Plans**
On-campus sections will not require changes in class scheduling, while online sections can be implemented asynchronously.

3. **Space**
No additional space requirements are necessary for this certificate.

4. **Faculty Resumes**
The associated faculty who have taught or can teach the related courses are given below. Examples of faculty webpages are embedded with the faculty names.

PH 4390: Robert J Nemiroff (Physics)
PH 5395: Elena Giusarma (Physics)
CS/EE 5841: Xiaoyong Yuan (Applied Computing/Computer Science)
UN 5390: Gowtham (Electrical and Computer Engineering/Physics)
CS/EE 5821: Timothy Havens (Electrical and Computer Engineering)

Approval Process
Department approval: January 22, 2021
College of Sciences and Arts: February 15, 2021
Graduate Faculty Council: March 2, 2021
Provost's Office and Deans' Council: March 15, 2021
Approval by the Senate:
Approval by the President: