November 6, 2023

THE OHIO STATE UNIVERSITY DEPARTMENT PHYSICS

Dear ASC Curriculum Review Committee:

Appended is a revised proposal by the Department of Physics for a Computational Physics Certificate, type 1b (undergraduate academic certificate, embedded).

The rationale for this certificate is that many students majoring in Physics, Engineering Physics and Astronomy arrive at Ohio State with an interest in computers and software development. Computation is an integral part of modern science and the certificate in computational physics is designed to educate students in computer simulation of physical systems. A certificate in computational physics proves to a future employer or graduate program that the student is skilled in modeling physical systems and delivering solutions through computer programming.

The proposal has already undergone a review by the ASC Curriculum Review Committee in February and again in September. The present revised proposal implements the comments from the review.

This proposal has been approved by the Physics Undergraduate Studies Committee and Physics faculty. Also, concurrence for this certificate has been obtained from the Department of Electrical and Computer Engineering (ECE) and Statistics. Concurrence from CSE was sought but we did not receive a response. Note that Statistics 5730 was added to the certificate curriculum as an elective based on the recommendation of the Dept. of Statistics. This is a two credit hour course so we therefore reduced the minimum hours required for the certificate from 13 to 12.

The proposed implementation for this certificate is Autumn 2024.

Thank you for your consideration of this revised proposal.

Sincerely yours,

Thomas J. Humanic

Thomas J. Humanic
Professor of Physics
Vice-Chair for Undergraduate Studies

Proposal for an undergraduate embedded Certificate in Computational Physics

November 6, 2023

Proposal Submission Guidelines for Establishing a New Certificate

1. Required Information

- Name of proposed certificate. Identify certificate type from certificate grid (*e.g.*, Type 2, standalone post-bachelor undergraduate certificate).

  Computational Physics, type 1b (undergraduate academic certificate, embedded)

- Indicate whether the certificate will be delivered wholly on-line, wholly in-person, a combination, or with all hybrid courses.

  In-person delivery.

- Proposed implementation date.

  Autumn 2024

- Academic units (e.g., department, college) responsible for administering the certificate program.

  The Department of Physics, in the College of Arts and Sciences will be responsible for administrating the certificate program. The Department of Physics Vice-Chair for Undergraduate Studies and Director of Undergraduate Studies along with the Undergraduate Studies Committee is the administrative structure that will oversee the certificate program, managing assessment, changes and other administrative issues that may arise with the program.

2. Rationale

- Describe the rationale/purpose of the certificate.

  Many students majoring in Physics, Engineering Physics and Astronomy arrive at Ohio State with an interest in computers and software development. Computation is an integral part of modern science and the certificate in computational physics is designed to educate students in computer simulation of physical systems. Computational physics prepares students to build computational models, design algorithms for numerical solutions, analyze the calculated data and perform computer experiments, (that are otherwise unfeasible), by using high-performance computers. A certificate in computational physics proves that students are skilled in modeling physical systems and delivering solutions through computer programming.

A good example of the interest of employers in computational physics is found with the Office of Science of the U. S. Department of Energy (DOE). The DOE supports over 40 percent of the basic research in physical sciences in the United States and operates 10 major laboratories, such as the Argonne National Laboratory, Princeton Plasma Physics Laboratory, and SLAC National Accelerator Laboratory. Its Advanced Scientific Computing Research (ASCR) program promotes careers in computational physics and the use of tools to analyze, model, simulate, and predict complex phenomena important to the DOE. In 2001, it began the Scientific Discovery through Advanced Computing (SciDAC) program that supports many computational physics jobs. The program is focused on advancing scientific discovery using supercomputers performing trillions of calculations per second (tera-scale). SciDAC projects are aimed at "developing future energy sources, studying global climate change, accelerating research in designing new materials, improving environmental cleanup methods, and understanding physics from the tiniest particles to massive supernovae explosions." SciDAC publishes a journal and has established SciDAC Institutes at four major universities with a total of 13 universities participating in the partnership.

Ohio State has significant strength in computing, but no well-defined program in computational physics. This certificate will clarify to students, grad schools, and employers that the student was engaged in a coherent set of undergraduate coursework to prepare the student to pursue computational physics as a career or to use it in graduate school.

- Identify a likely source of student demand for the proposed certificate, and provide one or two examples.

  Students majoring in these programs will be able to indicate their focus on computational physics with such a certificate with a minimum of extra courses.

  For example, a student majoring in Physics, Engineering Physics or Astronomy will be able to complete the certificate with 2 additional courses with strategic choices within the major.

- Provide the following statement: *Upon completion of the academic certificate in* <specify title>*, learners will be better prepared to. . .*" <list a maximum of 3 outcomes>.

  Upon completion of the academic certificate in Computational Physics, students will be better prepared to :
  (1) Write correct, clear, and well-documented computer code without errors that flows logically and is appropriate for solving physics problems
  (2) Explain which machine learning algorithm or other computational solution should be used to solve a physics problem
  (3) Articulate verbally or in writing the importance of being able to solve physics technical problems computationally versus relying solely on analytical methods

See appendix C for assessment plan.

3. Relationship to Other Programs / Benchmarking

- Identify any overlaps with other programs or departments within the university. Append letters of concurrence or objection from related units.

  The certificate overlaps with the BS in Physics and the BS in Engineering Physics, both of which are administered by the Department of Physics.

  Concurrence for this program has been obtained from the Department of Electrical and Computer Engineering (ECE) and Statistics. We sought concurrent from CSE but did not receive a response.

- Indicate whether this certificate or a similar certificate was submitted for approval previously.

  This is a new proposal. No such certificate proposal has been submitted for approval previously.

  Explain at what stage and why that proposal was not approved or was withdrawn.

  N/A

- Identify similar programs at other universities in Ohio or in the United States and their levels of success.

  There are no similar programs in Ohio.

  There are several undergraduate certificate programs in computational science that specialize in physics, two examples being at the University of Illinois at Urbana-Champaign offered by the College of Engineering https://cse.illinois.edu/cse-educational-programs/undergraduate-certificate/ , and at the University of Missouri offered by the College of Arts and Science, http://catalog.missouri.edu/collegeofartsandscience/additionalcertificatesminors/cert-computational-physics/ . The certificate programs offered by these universities are similar in scope with the certificate program being proposed here.

4. Student Enrollment

- Indicate the number of students you anticipate will choose to pursue this certificate.

  Based on a recent survey of our current majors, we anticipate initial enrollment to be modest, about 20-40. Growth will be facilitated with outreach to the relevant populations in Physics, Engineering Physics, Astronomy and ECE. The Undergraduate Studies

Committee in Physics will advertise the certificate during student visit days, communicate the opportunity to advisors and the career center

.

5. Curricular Requirements

- Provide ASC certificate advising sheet.

  See Appendix A

- List the courses (department, title, credit hours, description) which constitute the requirements and other components of the certificate. If any courses have prerequisites, please indicate so. Indicate which courses are currently offered and which will be new. When new course requests are submitted through curriculum.osu.edu, indicate that those course requests are being submitted as part of a new certificate proposal. As much as possible, the curriculum committees will review the course requests in conjunction with the certificate proposal.

  Each student completing the certificate will be required to take two courses offered by the Department of Physics in computational physics, and two elective courses from the list given in the tables below. Students will be able to overlap their curriculum by 50%, as permitted by the rules of the certificate. ***All courses listed are currently offered.***

Required courses – All students must take the two courses listed below.

Course number	Course Name	Credit hours	Prerequisites
Physics 5680	Big Data Analytics in Physics *Provides an introduction to machine learning and advanced algorithms, with an emphasis on practical physics-based applications, using publicly available data sets. The goal is to provide an introduction to Data Science for students who may want to pursue this as a career option and/or apply these techniques in a research environment.*	3	Enrollment in the Physics, Astronomy, Engineering Physics major; C- or higher in CSE 1222, CSE 1223, Engineering 1281H, or Astronomy 1221; C+ or higher in Physics 1251, or instructor permission.
Physics 5810	Topics in Computational Physics *Experimental and theoretical aspects of areas of current interest in computational physics.*	4	Physics 5500 or 5500H; and CSE 1222, 1223, 1224, Astron 1221, Engr 1221, or 1281H; or permission of instructor.

Elective courses – Students must take two courses from the list below.

Course number	Course Name	Credit hours	Prerequisites
CBE 5780	Molecular Dynamics Simulations *Students learn to use standard open-source software to carry out molecular dynamics simulations on a supercomputer.*	3	Junior standing or above in Chemistry, Engineering, or Physics
Math 3607	Beginning Scientific Computing *Introduction to mathematical theory of algorithms used to solve problems that typically arise in sciences, engineering, and finance.*	3	C- or better in Math 2255 and Math 2568 or equivalents
CSE 5361	Numerical Methods *Numerical methods for scientific computation: computer arithmetic, rounding errors, machine precision, machine representation, root-finding, interpolation, integration, linear systems, splines, smoothing, curve-fitting, linear programming*	3	Math 2231, Math 2568, and Math 1151
STAT 3201	Introduction to Probability for Data Analytics *An introduction to probability and its role in statistical methods for data analytics. Equal emphasis is placed on analytical and simulation-based methods for quantifying uncertainty. Approaches to assessing the accuracy of simulation methods are discussed. Applications of probability and sampling to big-data settings are discussed.*	3	Math 1152, 1161.xx, 1172, 1181, or equiv; or permission of instructor. Note that it is recommended that students who choose Statistics 3201 as an elective take the course prior to Physics 5680.
STAT 5730	Introduction to R for Data Science *Introduces underlying concepts of the R programming language and R package ecosystem for manipulation, visualization, and modeling of data, and for communicating the results of and enabling replication of their analyses.*	2	Statistics 1350.xx, 1405.xx, 1550, 2450.xx, 2480.xx, 3201, 3202, 3450.xx, 3460, 3470.xx, 4202, 5301, or 5302, or equivalent; or permission of instructor.

ECE 5510	Introduction to Computational Electromagnetics *Numerical methods for solving maxwell equations both static and electrodynamics, introduction to finite difference, finite element and integral equation methods, and applied linear algebra.*	3	ECE 3010, Physics 5400, or permission by instructor
Math 5601	Essentials of Numerical Methods *Systems of linear equations, linear least squares, eigenvalue problems, nonlinear equations and optimization, interpolation, numerical integration and differentiation, numerical solution for ODEs, IVPs and BVPs.*	3	4556 and 2568 or permission by instructor

- State the minimum number of credits required for completion of the certificate.

  Total 12 hours
  .
- Indicate the number of semesters expected to complete the certificate. Confirm that courses are offered frequently enough and have the capacity to meet this expectation.

  4 semesters, Note that there is sufficient frequency of courses so that there is at least one course a student may take each semester. Every course is offered at least on alternate years. The courses have the capacity to meet the enrollment expectation.

- If applicable, describe existing facilities, equipment, and off-campus field experience and clinical sites to be used. Indicate how the use of these facilities, equipment, etc., will impact other existing programs.

  Resources from the Ohio Supercomputer Center will be used in several of the courses that are offered for the certificate.

- For interdisciplinary certificates, describe the way in which advising and other student support will be provided.

  N/A.

- If applicable, describe additional university resources (including advisors and libraries) that will be required for the new certificate.

Advising and students support services are available through the department, college, and university, as is available to any student pursuing a program. In Physics, L. Thaler and D. Zach provide undergraduate student advising.

- Provide ASC completion sheet for certificates.

  See Appendix B

- Provide semester-by-semester sample program.

  Year 1:
  Math 3607 (Autumn) or Physics 5680 (Autumn)
  Physics 5810 (Spring) or CSE 5361 (Spring)
  Year 2:
  Physics 5680 (Autumn) or CBE 5780 (Autumn)
  CSE 5361 (Spring) or Physics 5810 (Spring)

Appendices

Appendix A: Advising Sheet

The Ohio State University
College of Arts and Sciences

Computational Physics Certificate, Type 1b

Advising Contact:
Ms. Lindsey Thaler
Director of Undergraduate Studies
Academic Advisor for Physics and Engineering Physics
Office: 1142 Physics Research Building
Email: thaler.21@osu.edu

Mr. David Zach
Academic Advisor for Physics and Astronomy
Offices: 1140 Physics Research Building (MThF); 4012 McPherson Lab (TuW)
Email: zach.11@osu.edu
Phone: 614-292-1358

Faculty Contact:
Dr. Thomas Humanic
Vice Chair for Undergraduate Studies
Office: 2144 Physics Research Building
Email: humanic.1@osu.edu
Phone: (614) 247-8950

The Computational Physics certificate will clarify to students, grad schools, and employers that the student was engaged in a coherent set of undergraduate coursework to prepare the student to pursue computational physics as a career or to use it in graduate school.

Course pre-requisites: Note that there are significant pre-requisites for all required and elective courses, and that students who are outside of the physics, engineering physics, and astronomy majors should speak with an academic advisor before attempting to pursue the certificate.

The Computational Physics certificate requires a minimum of 12 credits drawn from Physics and other departments and distributed as follows:

Take all of the following Physics courses:

Physics 5680: Big Data Analytics in Physics (3 credits)

Physics 5810: Topics in Computational Physics (4 credits)

Students will take two courses in other departments from the following list:

CBE 5780: Molecular Dynamics Simulations (3 credits)

Math 3607: Beginning Scientific Computing (3 credits)

CSE 5361: Numerical Methods (3 credits)

STAT 3201: Introduction to Probability for Data Analytics (3 credits)

STAT 5730: Introduction to R for Data Science (2 credits)

ECE 5510: Introduction to Computational Electromagnetics (3 credits)

Math 5601: Essentials of Numerical Methods (3 credits)

Computational Physics Certificate Program Guidelines

Credit hours required: A minimum of 12.

Overlap with degree program: A student is permitted to overlap up to 50% of credit hours between other degree program (major, minor, other certificate, or general education) and the certificate program.

Grades required
• Minimum C- for a course to be counted on the certificate
• Minimum 2.00 cumulative GPA for all certificate course work.

Certificate approval: The certificate may be approved by the student's assigned academic advisor via the Degree Audit Report (DAR). If the certificate is not complete on the DAR, the student must consult with a Department of Physics advisor, either Lindsey Thaler or David Zach (see contact information above).

Filing the certificate program form: The certificate form must be filed at least by the time the graduation application is submitted to a college/school advisor.

Appendix B: Certificate Completion Sheet

College of Arts and Sciences

Computational Physics Certificate Program

Student name: _____

Student OSU Email: _____

Certificate Advisor Name: _____

Required Courses (7 credits):

Course (Hours)	**Course Grade**	**Term Completed**
Physics 5680: Big Data Analytics in Physics (3 credits)		
Physics 5810: Topics in Computational Physics (4 credits)		

Elective course -- Students must take two courses from this list (minimum 5 credits):

Course (Hours)	**Course Grade**	**Term Completed**
CBE 5780: Molecular Dynamics Simulations (3 credits)		
Math 3607: Beginning Scientific Computing (3 credits)		
CSE 5361: Numerical Methods (3 credits)		
STAT 3201: Introduction to Probability for Data Analytics (3 credits)		
STAT 5730 (2 credits)		
ECE 5510: Introduction to Computational Electromagnetics (3 credits)		
Math 5601: Essentials of Numerical Methods (3 credits)		

Total credits (12): _____

Certificate Advisor Signature: _____

Date: _____

Appendix C: Assessment Plan

Upon completion of the academic certificate in Computational Physics, students will be better prepared to:

(1) Write correct, clear, and well-documented computer code without errors that flows logically and is appropriate for solving physics problems
(2) Explain which machine learning algorithm or other computational solution should be used to solve a physics problem
(3) Articulate verbally or in writing the importance of being able to solve technical problems computationally versus relying solely on analytical methods

Assessment of the objectives of the certificate program will be carried out using direct and indirect measurements. In particular, the following data will be collected and analyzed to improve the quality of the program:

Learning outcome	**Data source (course/assignment)**	**Assessment method**	**Reporting schedule**
(1) Write correct, clear, and well-documented computer code without errors that flows logically and is appropriate for solving physics problems	Physics 5810 (Computational Physics) final project	Direct At least 70% of students will score 11 points (corresponding to "adequate") or more on the final project in the categories of: - execution (code runs) - commenting - code structure - axes labels - legends - names (variable and function names are self-explanatory)	Once per year at the end of spring semester
	Computational Physics Certificate Exit Survey	Indirect Students report an average score of a 3	Each semester a student is graduating

		(out of 5) or higher in agreement that this outcome has been met.	from the certificate program
(2) Explain which machine learning algorithm or other computational solution should be used to solve a physics problem	Physics 5680 (Big Data Analytics in Physics) final project	Direct 70% of students score a 75% (6 out of 8) or higher on the final project in the categories of: - student adequately explains the algorithm used and why - student adequately explains the results of the project	Once per year at the end of autumn semester
	Physics 5810 (Computational Physics) final project	At least 70% of students will score 11 points (corresponding to “adequate”) or more on the final project in the category of: -physics (code implements the appropriate physics for the problem)	Once a year at the end of spring semester
	Computational Physics Certificate Exit Survey	Indirect Students report an average score of a 3 (out of 5) or higher in agreement that this outcome has been met.	Each semester a student is graduating from the certificate program

(3) Articulate verbally or in writing the importance of being able to solve technical problems computationally versus relying solely on analytical methods	Physics 5680 (Big Data Analytics in Physics) final project	Direct 70% of students score a 75% (6 out of 8) or higher on the final project in the category of: - student adequately explains the problem their project focuses on and importance of solving the problem	Once a year at the end of autumn semester
	Physics 5810 (Computational Physics) final project	At least 70% of students will score 11 points (corresponding to "adequate") or more on the final project in the category of: - validation (provides validation through error analysis, and/or comparison to known solutions/limiting cases)	Once a year at the end of spring semester
	Computational Physics Certificate Exit Survey	Indirect Students report an average score of a 3 (out of 5) or higher in agreement that this outcome has been met.	Each semester a student is graduating from the certificate program