CAAL
10/27/22
Agenda Item 8.a

New Program Proposal
Doctorate in Mathematics with Computation
College of Charleston

Executive Summary

College of Charleston requests approval to offer a program leading to the Doctoral Program in Mathematics with Computation in Fall 2023. The proposed program is to be offered through traditional delivery mode. The following chart outlines the stages of approval for the proposal. The Advisory Committee on Academic Programs (ACAP) voted unanimously to recommend approval of the proposal in Fall 2019. The full program proposal and support documents are attached.

Stages of Consideration	Date	Comments
Program Proposal Received	8/1/19	Not Applicable
ACAP Consideration	9/15/22	Representatives from the College of Charleston proposed the Doctoral Program in Mathematics with Computation. The program was approved by ACAP in Fall 2019. The discussion included clarification of the projected enrollment, curriculum formation and dissertation model. The proposal highlighted the flexible individual-centered instruction and research program that focuses on a developing high level technical ability, and long-term project skills for interested students. With a research emphasis, graduates will be uniquely trained to seek employment in the scientific and technical sectors such as industry, laboratories, science policy jobs, and technology start-up companies. The proposal indicated the support of full-time and part-*time option* to accommodate local working students. With a flexible delivery option, the proposed program will offer all classes in late afternoons and evenings, and seminars at convenient times. No additional comments or suggestions were provided. ACAP voted unanimously to recommend approval of the program proposal. ***(9/12/2019)*** The proposal was presented again at the ACAP meeting on September 15, 2022. No additional comments or suggestions were provided.

Requested Action

The Committee on Academic Affairs and Licensing approve College of Charleston's program leading to a Doctorate in Mathematics with Computation to start in Fall 2023.

College of Charleston Undergraduate Student and Program Data

Undergraduate In-/Out-of-State Enrollment, Fall 2018	6,391 (64.69%) / 3,489 (35.31%)
Number of Approved Programs in 10 Yrs. (FY 2010-2019)	24
Number of Terminated Programs in 10 Yrs. (FY 2010-2019)	7

Industry related Occupational Wages and Projections in South Carolina, 2020 – 2030*

Occupational Field [1]	2021 Entry Level [2]	2021 Median Income [2]	2020-2030 Estimated Employment [3]	2020-2030 Projected Employment [3]	2020-2030 Employment Change [3]	2020-2030 Annual Avg. Percent Change [3]	Total Percent Change [3]
Computer and Mathematical	$43,850	$77,500	47,453	55,770	8,317	2%	18%

[1] "Occupational Field" represents the closest related occupation category that includes the occupations aligned with the program proposal.
[2] SC Department of Employment & Workforce (DEW), Labor Market Information. (2022). Occupational Employment and Wage Statistics (OEWS) for All Major Groups in South Carolina in 2021 [Data file]. Retrieved from https://jobs.scworks.org/vosnet/lmi/default.aspx?plang=E
[3] SC Department of Employment & Workforce (DEW), Labor Market Information. (2022). Occupational Employment Projections (Long-term) for Multiple Occupations in South Carolina in 2020-2030 [Data file]. Retrieved from https://jobs.scworks.org/vosnet/lmi/default.aspx?plang=E
* Data downloaded September 15, 2022; Most recent data available.

ACAP
9/15/22
Agenda Item 3

NEW PROGRAM PROPOSAL FORM

Name of Institution: College of Charleston

Name of Program (include degree designation and all concentrations, options, or tracks): Doctoral Program in Mathematics with Computation

Program Designation:

- ☐ Associate's Degree
- ☐ Bachelor's Degree: 4 Year
- ☐ Bachelor's Degree: 5 Year
- ☐ Master's Degree
- ☐ Specialist
- ☒ Doctoral Degree: Research/Scholarship (e.g., Ph.D. and DMA)
- ☐ Doctoral Degree: Professional Practice (e.g., Ed.D., D.N.P., J.D., Pharm.D., and M.D.)

Consider the program for supplemental Palmetto Fellows and LIFE Scholarship awards?

- ☐ Yes
- ☒ No

Proposed Date of Implementation: Fall 2023

CIP Code: 27.0503

Delivery Site(s): College of Charleston, Charleston SC, Main Campus.

Delivery Mode:

- ☒ Traditional/face-to-face
  *select if less than 25% online
- ☐ Distance Education
  - ☐ 100% online
  - ☐ Blended/hybrid (50% or more online)
  - ☐ Blended/hybrid (25-49% online)
  - ☐ Other distance education (explain if selected)

Program Contact Information (name, title, telephone number, and email address):

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Institutional Approvals and Dates of Approval (include department through Provost/Chief Academic Officer, President, and Board of Trustees approval):

1. Department of Mathematics: April 16, 2018
2. Dean, School of Sciences and Mathematics: October 03, 2018
3. Provost's Office: November 29, 2018
4. Academic Planning Committee: November 29, 2018
5. Budget Committee: December 03, 2018
6. Committee on Graduate Education: January 11, 2019
7. Graduate Council: January 25, 2019
8. Faculty Senate: February 05, 2019
9. Board of Trustees: April 12, 2019

Background Information

State the nature and purpose of the proposed program, including target audience, centrality to institutional mission, and relation to the strategic plan.

The College of Charleston proposes the establishment of an innovative doctoral program in *Mathematics with Computation* primarily targeting a select group of highly talented individuals who are either bound or drawn to Charleston for a variety of reasons.

The proposed program will:

- Offer flexible individual-centered instruction and research training, whether focused on a specific mathematical area or centered upon broader interdisciplinary studies.
- Develop broad research training, high level technical abilities, and long-term project skills for individuals interested in employment in the scientific and technical sector (such as industry, laboratories, science policy jobs, and technology start-up companies).
- Provide doctoral candidates with unique opportunities and extensive support to develop their teaching skills in an environment where excellence in undergraduate instruction is a top priority.
- Continue and enhance the tradition of nurturing a close-knit group of graduate students and mathematics undergraduates, offering additional opportunities for vertically integrated research in teams, and providing our undergraduate majors with an exceptional learning experience with increased opportunities for one-to-one attention and small group learning.
- Build upon the strong research qualifications and achievements of several groups and individual faculty members in the Mathematics Department.
- Allow graduates from other mathematics programs to study under the tutelage of our internationally recognized research faculty.

A number of innovative features are incorporated in the proposed doctoral program:

- **Selective and small-sized.** The program is designed for students who already hold a Master's degree in mathematics or a closely related area, and is intended to be small, graduating 2 to 3 students per year. The program will mostly target academically strong individuals who reside in the Charleston area, but also consider excellent applicants from elsewhere who wish to undertake

research under the mentorship of a particular faculty member. Compared to many traditional doctoral programs, the post-Master's design allows maintaining the integrity and scope of the existing master's degree, as distinct from the doctoral program, and controlling the quality of the doctoral students. Its small size and selectivity will make it possible to use a holistic approach to nurturing many aspects of the student's development.

- **Part-time option: serving our local community.** The envisioned program will have a *part-time option* to accommodate local working students for whom moving elsewhere to pursue a mathematics PhD is not a possibility. The program will continue to offer all classes in late afternoons and evenings, and seminars at convenient times, and will expand flexible delivery options. Also, its small scale and research focus allow greater flexibility in creating programs of study that match the interests and aspirations of individual students.
- **Emphasis on research.** The proposed 42-credit hour program requires a minimum of 18 hours of graduate coursework and at least 18 hours of dissertation work. Students will enter with a Master's degree and will be able to proceed to a dissertation after limited coursework. This design allows an early focus on research, with the added benefit of minimizing cost. The strong focus on research, the close relationship with faculty mentors, and the team-driven research model will result in high quality research output and help establish the reputation of the envisioned doctoral program.
- **Vertically Integrated Research Teams.** All doctoral students will be expected to join vertically integrated research teams of undergraduate and graduate students and their research mentors. These "dream teams" can aim for powerful research results, because of the longer project time scales and the various levels of exploration and depth, and spur robust research seminars. Topics could include novel approaches to data analysis, aspects of representation theory and category theory, and integrable systems (these are topics covered in recent faculty/MS student seminars). We will employ a variety of tools and approaches to ensure that every doctoral student, whether full-time or part-time, will be fully engaged in her/his research team. These will include: hybrid format for courses, seminars, and brainstorming sessions; block scheduling of advanced courses; Saturday mini-workshops and group meetings; and online team collaboration software.
- **Computational component**. All students in the program must complete a computational project that will become an integral part of the dissertation. The computational project will involve some aspect of the dissertation, and may build on work done by a research team. Computational projects support the research of the integrated team as well as the dissertation in one or more of the following ways: through the design of new computational methods or tools to advance mathematical understanding (including algorithms, symbolic software packages, and visualization); through computer-assisted proofs and experimental mathematics (i.e. formal results inspired by experimentation, conjectures suggested by experiments, and data supporting significant hypotheses); and through the development of large numerical or statistical codes yielding new mathematical data. Students will be exposed to appropriate computational tools commonly used in various areas of mathematics in the core course sequences.

The proposed program aligns well with the central mission of the College, which states that the College of Charleston *… strives to meet the growing educational demands primarily of the Lowcountry and the state and, secondarily, of the Southeast …* and … *anticipates offering a limited number of doctoral degrees should location and need warrant.*

Mathematics is inherently central to the liberal arts because it strives to *understand the world by performing formal symbolic reasoning and computation on abstract structures* and *understanding deep*

relationships among these abstract structures[1]. Mathematics is also the backbone of many areas of science, and both industry and engineering require increased mathematical sophistication due to the widespread use of computer simulations and the massive data sets integral to industry success.

The proposed program supports three main tenets of the College's mission and strategic plan:

- *A strong liberal arts and science tradition that places undergraduates first*: housed within a vibrant research-oriented and yet strongly student-focused department, such a small-sized, selective program will enhance the experience of students that excel academically, including recruiting and retaining ambitious undergraduates attracted by a robust research environment, and benefiting from a wider range of scholarly activities and more opportunities for intellectual growth.
- *Encourage and support research* of students at all levels through vertically integrated teams of undergraduates, graduate students, and faculty mentors. Peer mentoring and mixed cohorts have strong impact on student preparation and retention at all levels, and this will particularly enhance our undergraduate students, also by creating early opportunities for research involvement and increasing mentoring effectiveness.
- *Meet the rapidly growing demand for all levels of education* in Charleston and the Lowcountry area. In particular, as increasing numbers of high-tech companies seek to hire people with a strong mathematical training and facility with computations, the proposed PhD in Mathematics with Computation, with its part-time option, will fulfill this need in a unique and innovative way.

This program has the support of regional industry and members of the local high-tech community (see below and attached) and has been externally reviewed by Dr. Douglas Cenzer, Professor and former Department Chair of Mathematics at the University of Florida (see the positive evaluation report attached).

Assessment of Need

Provide an assessment of the need for the program for the institution, the state, the region, and beyond, if applicable.

The proposed doctoral program in Mathematics with Computation will help address the following main challenges for our city, region, and state:

- South Carolina has been experiencing a steady growth in the technology sector. A recent article in the Post and Courier reports that, while the state growth rate in this sector is above national average, "growing the tech sector has become an increasing focus for the state's economic development officials". The path to achieve this is continued commitment to "training and educating a workforce that will be ready to fill the needs of every company that chooses to do business in South Carolina — including those in the ever-evolving technology industry." (Governor Henry McMaster.)[2]
- Charleston is in a particularly fortunate situation, as one of the fastest-growing regions in the U.S. and a mecca for millennials, many of whom are attracted by a relatively affordable lifestyle and

[1] The Mathematical Science in 2025. The National Academies Press. 2013.

[2] *South Carolina's technology sector grew steadily last year, adding 2,500 job,* by T. Moore. The Post and Courier, April 2, 2018. https://www.postandcourier.com/business/south-carolina-s-technology-sector-grew-steadily-last-year-adding/article_56b6f124-3392-11e8-a752-5b4b0d4ed286.html

by many innovative tech companies and start-ups in industries including healthcare, HR, cybersecurity, real estate, and e-commerce. "Charleston's next big challenge is attracting the volume of talent necessary to sustain its growth".[3]

- Charleston currently has many highly talented individuals who do not have access to the highest level of education achievable in their fields of interest. These include several exceptional graduates of our undergraduate and master's programs who are bound to Charleston for family or employment reasons. Some would become high-impact educators, were they offered the opportunity to earn a doctorate, while some others would gain substantial career advancement with such a degree. Eventually, inability to fulfill intellectual ambitions and reach full potential will drive talent away from the region.

Furthermore:

- A 2017 program review of our Master's Program in Mathematical Sciences conducted by external evaluators included an assessment of the potential for the development of a doctoral program. The following are excerpts from the program, pertaining in particular to the local need for such a program:
    - *Given the excellent credentials of the mathematics graduate faculty, we believe the department of mathematics would be a perfect candidate for developing a new Ph.D. program. ...*
    - *The faculty are extraordinarily active in research and scholarship. On average their research and scholarship productivity is on par or exceeds the productivity of faculty at peer or aspirational institutions.*
    - *… the influx of high technology companies into Charleston, which some say is earning Charleston the moniker "Silicon Harbor", and the fact that there are currently no mathematics Ph.D. programs in the Charleston metropolitan area, makes the city a prime candidate for such a program. If the Department of Mathematics at CofC does not fill the void, its competitors will. ...*
    - *To not take advantage of this current opportunity would seem to have potentially harmful effect down the road, relegating CofC into a closed and insular niche future.*

- An assessment of the level of interest of various industries, through some of our locally employed students, advisory board members, and other parties, indicated widespread interest in having such a program, and companies reacted enthusiastically to the part-time option, not typically available in many other cities, and the computational component of the proposed program. As indicated in the support letters, the part-time option is appealing to employers as it allows highly talented employees to pursue doctoral degrees locally, thus helping prevent brain-drain. It will also attract well-qualified and ambitious individuals to a city that has been developing a more comprehensive research infrastructure. The computational component and the vertically integrated research teams will train modern mathematicians who are at ease with both high-level mathematics and relevant computational tools and who are able to work collaboratively and effectively communicate across various levels of technical expertise. These will be highly desirable employees in multiple settings: high-tech industry, research labs, and academia.
- Attached to this proposal, please find support letters from Boeing, Benefitfocus, DeepDB, Hawkes Learning Technologies, and scientists/mathematicians at IBM, IOHK, DataStax, Google, Ground

[3] *How a population boom is fueling Charleston tech scene*, by David Ginn (President and CEO of the Charleston Regional Development Alliance). 7/2/2018 on venturebeat.com

Swell Capital, Galois, and Cognitect as well as the Charleston Digital Corridor which represents a broad swath of the tech companies in Charleston: Anatta Design, Atlatl Software Inc, Auto Tech Labs, AVOXI, Benefitfocus, Inc., BiblioLabs, LLC, Blackbaud, BoomTown, Brain Power Software, Cantey Tech Consulting LLC, CarePoint, Catalytic Data Science, Ceterus, Charityproud, Booz Allen Hamilton's Charleston Digital Hub, CodeLynx, Inc., College of Charleston IT, Comcast Business, Class, Commit Good, Critical Mix, CSS International, Inc., Customer Imperative, Dispute Resolution Data, Eat Drink Healthy, eFundYourHealth, eGroup, Electronic Health Network, Inc, Elevar, Fount, Fracta, FusionPoint, Galois, Google, Heatworks, Home Telecom, Immedion, Industrica, Inc., Lynker Technologies, Mixonian Institute, Modus21, Moovila, Inc., Morgan 6, N3TWORK, netGALAXY Studios, Netrist Solutions, Omatic Software, One Data Soure, Palmetto Digital Marketing Group, Palmetto, Partners, LLC, PhishLabs, Portone Technology Group, LLC, SageSmith Consulting, Scientific Research Corporation, Seller Labs, sineLABS, Skyline Exhibits & Design Inc., Snag, Sovi, StraCon Services Group LLC, Surety Bonds Direct, Tabula Rasa Healthcare, TalkTools, Tallo, TBG Security, The MediaBeast Marketing Group, Turbo Medical Marketing, Visiture, Vizbii, Waitlist Me, Wave Sciences Corporation, and Workiva.

- Seeing that this program aims to enroll 8 students and produce 2-3 graduates per year, clearly this level of interest by the regional tech industry demonstrates the need for this program, the ability to recruit students into this program, the market for sustaining a highly selective program, and the opportunity for graduates to secure employment.

Transfer and Articulation

Identify any special articulation agreements for the proposed program. Provide the articulation agreement or Memorandum of Agreement/Understanding.

Not applicable at this time.

Employment Opportunities

Supporting Evidence of Anticipated Employment Opportunities
Provide supporting evidence of anticipated employment opportunities for graduates.

The local and regional job outlook for mathematicians reflect a larger trend at the national level.

(A) The **Occupational Outlook Handbook of the Bureau of Labor Statistics** has detailed analysis on job outlook for mathematicians[4]. There are several insights to draw from their data:

1. ``Employment in math occupations [actuaries, mathematicians and statisticians, and operations research analysts] is projected to grow 28 percent from 2020 to 2030, much faster than the average for all occupations, and will add about 67,200 jobs. Growth is anticipated as businesses and government agencies continue to emphasize the use of big data, which math occupations analyze." In particular, the job outlook for mathematicians and statisticians for the 2020-2030 decade is expected to grow even faster at around 33%.

[4] Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook*, Mathematicians and Statisticians, at https://www.bls.gov/ooh/math/mathematicians-and-statisticians.htm (visited July 09, 2022).

2. The typical entry-level degree requirement is a master's degree in mathematics or statistics. Some jobs are available for those with bachelor's degrees. However, the level of theoretical sophistication required for modeling and analyzing massive data sets will require at least a master's degree. This is because the mathematical tools being developed for Big Data modeling and analysis involve increasingly high-level mathematics skills as those typically acquired during doctoral training.

3. In private industry, mathematicians typically need an advanced degree, either a master's degree or a doctorate. For jobs with the federal government, candidates need at least a bachelor's degree in mathematics or significant coursework in mathematics. Many students who get a doctoral degree work as professors of mathematics in a college or university.

Quick Facts: Mathematicians and Statisticians	
2021 Median Pay	$96,280 per year $46.29 per hour
Typical Entry-Level Education	Master's degree
Work Experience in a Related Occupation	None
On-the-job Training	None
Number of Jobs, 2020	44,800
Job Outlook, 2020-30	33% (Much faster than average)
Employment Change, 2020-30	15,000

Table A: Employment figures and outlook for Mathematicians and Statisticians
(Bureau of Labor Statistics, Occupational Outlook Handbook. Updated April 18, 2022).

(B) The **American Mathematical Society** (AMS) conducts an annual survey of the profession, in collaboration with several other principal societies representing the mathematical sciences, including, e.g., SIAM (the Society for Industrial and Applied Mathematics), MAA (the Mathematical Association of America), and ASA (the American Statistical Association).[5]

The most recent *Report on the 2017-2018 New Doctorate Recipients*[6] contains employment data collected by two different surveys during or immediately after the year of graduation. We highlight a few results of these surveys:

1. Over a ten-year period, PhD degrees awarded in mathematics and statistics/biostatistics have increased by 42%, ``an approximate 3.6% year-over-year increase on average."
2. Over a comparable period, the unemployment rate first climbed from negligible to just above 7%, and has then fallen to below 6% since 2016, with women PhD unemployment falling faster (4.8% in 2018). This suggests an increase in demand of PhDs.
3. Business and Industry is one of the major employment sectors for recent US PhDs, employing 35% of the new recipients. More specifically, of the graduates who are employed in the US, 39% are employed in government, business and industry.
4. US non-academic employment has remained robust at 30%, 35%, 34%, 35%, 34% for 2014–2018 period.

[5] http://www.ams.org/profession/data/annual-survey/annual-survey (visited July 22, 2022)
[6] https://www.ams.org/profession/data/annual-survey/2018Survey-NewDoctorates-Report.pdf

5. Of the graduates who are employed in the US, 15% are employed in undergraduate oriented or master's institutions, and 14% in other academic and research institutes.
6. A postdoctoral researcher is a preferred first job; graduates from the more prestigious institutions are far more likely to be in post-docs. 50% of the new PhDs awarded by the Math Private Large group are employed in postdocs, while only 16% of new PhDs awarded by the Math Public Small group and 20% of PhDs awarded by the Statistics group are in postdocs. The typical duration of a postdoctoral assignment in the mathematical sciences is two years.

(C) **Local Projection**s. Projection Central has some statistics on State Occupational Projections, both long-term (2020-2030) and short-term (2021-2023) projections.

Not all occupations have data available for South Carolina, however:

Area	Title	Base	Projected	Change	%Change	Avg. Annl Openings
South Carolina	Mathematical Science Teachers, Postsecondary	400	430	30	7.5	40
South Carolina	Operations Research Analysts	920	1,210	290	31.5	100
South Carolina	Statisticians	320	450	130	40.6	40

Table B1: Long-term projections for selected occupations in the mathematical sciences.OBJ

Occupational Field	Estimated Employment	2028 Projected Employment	2018-2028 Total Employment Change	2018-2028 Annual Average Percent Change	Total Percentage Change	Median annual wage (Statistician)
Computer and Mathematical	42,251	49,290	7039	1.55%	16.666%	$67,140

Table B2: Long-term projections for Mathematical and Computer occupations.[8]

1. Jobs for mathematical sciences professors at two- and four-year colleges are projected to rise by 7.5% during the 2020-2030 decade. These positions increasingly require PhDs in the field.

2. Jobs for Operations Research Analysts and Statisticians (both areas are well represented in our department) are projected to grow at a rate of 31.5% and 40.6%, respectively, during the 2020-2030.

3. Computer and Mathematical jobs (the category most closely related to the proposed program) are projected to grow by 16.7% during the 2018-2028 decade.

Description of the Program

Explain how the enrollment projections were calculated.

We anticipate having only 2 full time and 6 part-time students enrolled in any given year (Table C). This corresponds to admitting an average of 2 full-time students over a three-year period and 6 part-time students over a 5-year period. Estimating 3-year completion for full-time students and 5-year for part-time students, this results in a steady state of 8 enrolled students and 2.2 degree awarded per year

[8] https://www.scworks.org (visited July 22, 2022)

(exceeding the CHE expected productivity for Doctoral-Research programs of 4.5 enrollments and 2 degrees awarded per year).

Given the interest expressed by various local parties, we expect to have a significantly larger pool of applicants. This will help with keeping the program selective and manageable. Full-time students will need to complete roughly 12 credit hours of work during a given academic year and 3 credit hours in the summer. Part-time students will need to complete roughly 6 credit hours during an academic year and 3 credit hours in the summer. The numbers in the table below were calculated by running 10,000 simulations of a continuous-time Markov chain and then rounded to integer values. We included years 10 and 15 as well as the projections for the first five years to show how the program will reach a steady-state of around 8 students.

PROJECTED TOTAL ENROLLMENT						
YEAR	**FALL**		**SPRING**		**SUMMER**	
	Headcount	**Credit Hours**	**Headcount**	**Credit Hours**	**Headcount**	**Credit Hours**
2023 (1)	2	12	2	12	3	9
2024 (2)	3	15	4	18	4	12
2025 (3)	4	18	5	21	5	12
2026 (4)	5	24	5	21	6	15
2027 (5)	6	24	6	24	7	18
2028 (10)	7	30	7	30	8	21
2039 (15)	8	32	8	32	8	21

Table C: Projected enrollments and credit hours.

Besides the general institutional admission requirements, are there any separate or additional admission requirements for the proposed program? If yes, explain.

☒Yes

☐No

Since the proposed program would be the first Ph.D. program at the College of Charleston, it will have admission requirements unique to the program, with the exception of the TOEFL/IELTS requirement for international students, which is an institutional graduate admission requirement. The Graduate Steering Committee, composed of graduate faculty in Mathematics, exists to support the current Masters Programs. This committee will expand to support activities for the Doctoral program (e.g. admissions, writing qualifying and comprehensive exams, developing and reviewing curriculum, and program assessment, among other tasks).

Admission requirements

Any decision regarding admission is made by the Graduate Steering Committee based on the application material and supporting documents:

- Hold a Master of Science (MS) in mathematics or statistics or its equivalent with at least a 3.5 GPA from a regionally accredited university or being an exceptional applicant with a mathematical preparation comparable to a Master of Science degree in mathematics or statistics.
- Mathematics subject GRE.
- TOEFL or IELTS (International students only).
- Two letters of reference.
- Statement of research intent, identifying research area and potential research mentor(s).
- Curriculum Vitae.

Curriculum

The program curriculum is designed for students who already hold a master's degree in the mathematical sciences, so it should roughly be compared to the last three year of a traditional doctoral program. It is focused on advanced course sequences and research. It incorporates training in computation culminating in a computational project as an integral part of the dissertation. Doctoral students are required to work in vertically integrated research teams lead by the doctorial advisor, consisting of undergraduate and graduate students (both M.S. and Ph.D. students) and faculty members. Courses are offered late afternoon and evening, accommodating part-time students working in the local community. Sample full-time and part-time timelines are provided at the end of this section.

Total Credit Hours Required: 42

- Students must satisfy coursework, examinations, and dissertation requirements.
- Students must complete 18 hours of graduate core coursework, at least 9 of which at the 800-level, and a minimum of 18 hours of dissertation work to reflect the research emphasis of the program. The remaining 6 hours must be at the 800-level or dissertation.
- As part of the graduate course work, students must complete 3 two- semester sequences from the list of core courses.
- Students must complete a computational project as part of the dissertation work.
- The typical period for completing the program is three years for full- time students and five years for part-time students. Exceptions will be made according to the Graduate School Academic Policies and Procedures.

Program Requirements in Detail:

Qualifying Examinations

- Qualifying Examinations (QE) are comparable in content and level to written qualifying examinations of traditional doctoral programs.
- Each student must take a QE in advanced linear algebra, an QE in analysis, and an QE in either abstract algebra or mathematical statistics.
- Students interested in applying to the doctoral program will be given the opportunity to take MS-level courses to prepare for the QEs.

- QEs will be offered twice a year: during the summer and at the end of the fall semester. Students should complete the QEs the summer before entering the program and no later than the end of their first fall semester. A student who does not pass one or more exams will be given a second chance at the next offering. A maximum of two attempts is allowed; failure to pass any of the examinations on the second attempt will result in dismissal from the program.
- Though it is typically expected that students will take core courses or MS-level courses to prepare for (some of) the QEs, if suitably prepared, they may take any course except for Math 999, Doctoral Dissertation Research.

Core Courses (18 hours)

Students must complete a two-course sequence in three of the following areas:

Algebra
Analysis
Differential Equations or Dynamical Systems
Probability and Statistics
Scientific Computing and Numerical Analysis

In the core sequences, students will learn advanced mathematical content infused with the use of computational tools such as symbolic, computational, mathematical modeling, simulation, and numerical and/or statistical software packages, as appropriate to the given area. Students will be well prepared to conduct high quality, applied or theoretical work in this research-intensive doctoral program, and to make integral use of computational tools to advance their area of research through experimental mathematics, computer-assisted proofs, development of numerical or statistical codes yielding new mathematical data, and/or other computationally intensive methodologies.

Area	First semester	Second semester
Algebra	Math 604 Algebra II	Math 803 Algebra III
Analysis	Math 612 Real Analysis II	Math 811 Functional Analysis
Differential Equations *OR* *Dynamical Systems*	Math 623 Partial Differential Equations II	Math 823 Partial Differential Equations III
	OR	
	Math 624 Dynamical Systems	Math 824 Advanced Dynamical Systems
Scientific Computing and Numerical Analysis	Math 645 Numerical Analysis II	Math 845 Advanced Scientific Computing
Probability and Statistics	Math 630 Theory of Probability	Math 830 Theory of Stochastic Processes

Table D: Core sequences by area.

Comprehensive Examinations

- Students must complete two written Comprehensive Examinations (CEs), each covering material from one of the core sequences.
- Comprehensive Examinations are offered twice a year: once in summer and again in winter.
- Full-time students should complete both CEs during the summer following their first year in the program or no later than the end of the fall of their second year.
- Part-time students should complete both CEs by the summer following their second year in the program.
- A student who does not pass a CE will be given a second chance at the next offering.
- Failure to successfully complete either of the CEs within two attempts will result in dismissal from the program.

Dissertation Proposal Oral Examination

There will be a Dissertation Proposal Oral examination (DPO) administered by the dissertation advisory committee (comprised of appropriate graduate faculty) to determine if the dissertation topic is appropriate, and if the student is adequately prepared for work on the dissertation.

- Full-time students are expected to take the DPO before the end of the first year in the program.
- Part-time students are expected to take the DPO before the end of their second year in the program.
- The student must submit a dissertation proposal including a description of the problem to be investigated, an outline of the methodology to be used, and a bibliography at least two weeks before the DPO
- After the DPO, the dissertation advisory committee will approve the proposal, approve the proposal with minor revisions, or reject the proposal.
- The DPO may be repeated only once.
- Failure to successfully complete the DPO will result in dismissal from the program.

Note: The rationale for the timelines is based on the research-intensive focus of the program: students are expected to have identified a research area and possible advisors upon entering the program.

Dissertation and Doctoral Defense Examination

Students must write a dissertation under the direction of dissertation committee chair (doctoral advisor) to complete the program. The dissertation defense will be an oral examination conducted by the dissertation advisory committee. It is expected that the dissertation will contribute to advancing the relevant field of study and be publishable in a reputable journal.

Computational Project Component

All students in the program must complete a computational project that will become an integral part of the dissertation. Computational projects will lead to one or more of the following: creation of new computational methods or tools to advance mathematical understanding (including algorithms, symbolic software packages, and visualization); computer-assisted proofs and experimental mathematics (i.e. formal results inspired by experimentation, conjectures suggested by experiments, and data supporting significant hypotheses); development of large numerical or statistical codes yielding new mathematical data.

New Courses
List and provide course descriptions for new courses.

The following list includes the new courses created for the proposed doctoral program (800-level and above).

#	Course Number	Course Title	Description
1	MATH 803	Algebra III	This course is an introduction to category theory through a study of the category of modules as one of the best-behaved and the most studied categories. The list of topics includes basic category theory concepts and results as well as the concepts and results specific to the category of modules. 3 credits. Prerequisite(s): MATH 503 (Applied Algebra I), MATH 604 (Algebra II), or equivalent preparation. Admission to the PhD program in Mathematics with Computation or permission of the instructor.
2	MATH 811	Functional Analysis	This course is an application-oriented introduction to topics in functional analysis and is a continuation of Math 612. Topics covered include: normed spaces, Banach spaces, Hilbert spaces, bounded linear mappings, duality theory, reflexivity, Hahn-Banach theorem, open mapping theorem, closed graph theorem, Banach-Steinhaus theorem and the uniform boundedness principle, compact operators, and spectral theory. 3 credits. Prerequisite(s): MATH 612 (Real Analysis II), or equivalent preparation. Admission to the PhD program in Mathematics with Computation or permission of the instructor.
3	MATH 823	Partial Differential Equations III	Topics covered include: Sobolev spaces; second order elliptic equations; linear evolution equations; and Hamiltonian methods for evolution equations. The course includes student use of appropriate software to explore properties of evolution equations. 3 credits. Prerequisite(s): MATH 623 (Partial Differential Equations II) and MATH 511 (Real Analysis I), or equivalent preparation. Admission to the PhD program in Mathematics with Computation or permission of the instructor.
4	MATH 824	Advanced Dynamical Systems	This course will cover advanced topics in dynamical systems theory. Possible topics include Lyapunov exponents, advanced bifurcation theory, center manifold theory, ergodic theory, horseshoe maps, shift maps and symbol spaces, Sharkovskii's theorem, chaos, fractals, and perturbation theory. Possible applications include mechanics (Hamiltonian, Lagrangian, N-body problems), oscillator networks, spatio-temporal dynamics, and pattern formation. When possible, topics will be tailored to the interests of the students. The course includes student use of appropriate software currently used in dynamical systems, such as Mathematica, Matlab, and XPP/AUTO. 3 credits. Prerequisite(s): MATH 624 (Dynamical Systems), or equivalent preparation. Background in real analysis, metric spaces, and measure theory is highly recommended. Admission to the PhD

			program in Mathematics with Computation or permission of the instructor.
5	MATH 830	Theory of Stochastic Processes	This course covers advanced topics in stochastic processes such as Brownian motion, stochastic calculus, stochastic differential equations, Markov processes, weak convergence and semi-group theory. Applications to financial mathematics such as the Black-Scholes formula for derivative pricing and the Kalman-Bucy filter will also be studied. The course includes student use of R software which will be used for simulating stochastic processes. 3 credits. Prerequisite(s): MATH 560 (Stochastic Processes) and MATH 630 (Theory of Probability), or equivalent preparation. Admission to the PhD program in Mathematics with Computation or permission of the instructor.
6	MATH 845	Advanced Scientific Computing	This course is a continuation of MATH 645. It will address advanced topics from numerical methods for solving ordinary and partial differential equations, numerical linear algebra, and numerical optimization. Main topics: finite difference, finite volume, and finite element methods; conservation and conservation laws; geometric numerical integrators; solution of large sparse linear systems; constrained optimization methods; (and) important concepts of stability, convergence and error analysis; and issues of implementation. 3 credits. Prerequisite(s): MATH 645 or equivalent preparation as determined by the instructor. Programming skill in Python with Numpy, Matlab, or another scientific computing environment. Admission to the PhD program in Mathematics with Computation or permission of the instructor.
7	MATH 880	Advanced Special Topics	Advanced topics of current interest in areas of Mathematics or Statistics. May be repeated for credit, but only if different topics are covered. 3 credits. Pre-requisite(s): Permission of the instructor.
8	MATH 999	Doctoral Dissertation Research	Doctoral dissertation research and writing under the direction of a faculty advisor. 1-9 credits. Pre-requisite(s): Admission to the PhD program in Mathematics with Computation.

Table E: New course descriptions.

Timelines

The following table summarizes possible timelines for full-time and part-time options.

Sample Ph.D. Timelines		
Time	**Activities/Milestones**	
	Full-Time Students	**Part-Time Students**
Summer before Year 1	- Take Qualifying Examinations - Identify PhD faculty mentor (doctoral advisor)	- Take Qualifying Examinations - Identify PhD faculty mentor (doctoral advisor)

Year 1	- Focus of completing the core courses (up to three courses per semester)* - Participate in activities with your research team (e.g. seminars and group discussions) - Complete the Comprehensive Examinations during the summer	- Focus of completing core courses (one or two sequences)* - Participate in activities with your research team (e.g., seminars and group discussions) - Complete (at least) one of the Comprehensive Examinations during the summer
Year 2	- Complete the Dissertation Proposal Oral Examination during first semester - Select dissertation advisory committee Work on research project and develop a plan for the dissertation with the help of the dissertation committee chair (doctoral advisor) (MATH 999) - Elect to take an Advanced Special Topics course MATH 880) - Participate in and lead activities with your research team	- Focus of completing the core courses (remaining sequences)* - Complete the second Comprehensive Examination during the summer
Year 3	- Conduct research and write and document research results (MATH 999) - Participate in research activities with your research team - Elect to take an Advanced Special Topics course (MATH 880) - Complete and defend the dissertation (by the summer) - Graduate	- Complete the Dissertation Proposal Oral Examination during first semester - Select dissertation advisory committee - Work on research project and develop a plan for the dissertation with the help of the dissertation committee chair (doctoral advisor) (MATH 999) - Elect to take an Advanced Special Topics course (MATH 880) - Participate in and lead activities with your research group
Year 4		- Work on research project and implement plan for the dissertation with the help of the dissertation committee chair (doctoral advisor) (MATH 999) - Elect to take an Advanced Special Topics course (Math 880) - Participate in and lead activities with your research team
Year 5		- Conduct research and write and document research results (MATH 999) - Participate in research activities with your research team - Elect to take an Advanced Special Topics course (Math 880)

		- Complete and defend the dissertation (by the summer) - Graduate

Table F: Sample timelines for both full-time and part-time options.

***** Core sequence requirement. Three of: MATH 604-803, MATH 612-811, MATH 623-823 or MATH 624-824, MATH 630-830, MATH 645-845.

Note: These timelines can be adjusted when creating individual plans of study (e.g. Qualifiers can be taken at the end of the first semester).

Similar Programs in South Carolina offered by Public and Independent Institutions

Identify the similar programs offered and describe the similarities and differences for each program.

Some of the general aspects of the program that distinguish it from other programs across the state include (specific program differences are provided in table G below):

- As the local community moves toward increasing its research infrastructures, our program is designed to fill a niche for highly talented individuals wishing to pursue a doctoral program in the mathematical sciences without leaving their employment. The program is designed to support part-time completion of the degree requirements, by offering all of its courses during late afternoons and evenings and including part-time students in integrated research teams and program activities using a variety of modern tools. Part-time students will constitute the majority of students enrolled in the program.
- The computational component is a required component of the dissertation for all students, whether their research is in pure or applied mathematics. This reflects the increased relevance of computational tools in all areas of mathematics and will give graduates of the program a competitive advantage in industrial as well as higher education setting.
- The College of Charleston is a primarily undergraduate institution, known for its strong liberal arts and science core and emphasis on student research experiences. In harmony with these tenets of our institution, the program is designed to seamlessly integrate with our undergraduate program and to support and enhance the academic experience of our majors.
    - By keeping the size of the doctoral program small (with steady state enrollments of 6-8 students), the department can continue to provide personalized attention to all students.
    - Selectivity (admitting a few students with strong master's degrees and credentials) will result in successful teaching assistants (full-time students only) and leaders of vertically integrated research teams, who will support undergraduate students in a variety of ways.
    - The combination of small scale, master's entrance and research focus places less burden on the faculty and the department, given the small number of doctoral-level courses and students. This will make it possible to maintain the primary focus on undergraduate students.

- Mathematics majors, master's students, and other STEM majors will benefit from the increased research opportunities provided by the vertically integrated research teams. The increased and more structured collaborative environment will help all students develop communication skills when working with team members of diverse backgrounds and levels of knowledge.

We note that the some of the program features and practices are inspired by the long-standing, award-winning, research-focused mathematics Ph.D. program at Bryn Mawr College. Their mathematics department showcases a vibrant and diverse community of undergraduates, graduate students, and faculty in a liberal arts setting. The graduates of their small Ph.D. program routinely become postdocs at prestigious institutions and accept positions at top liberal arts colleges across the country.

Program Name and Designation	Institution	Similarities	Differences
Ph.D. in Biostatistics 60 credits	MUSC	MUSC courses BMTRY 785 *Probability and Statistics Inference*, and BMTRY 718 *Stochastic Processes in Biology and Medicine*, have some overlap with MATH 630 *Theory of Probability* and MATH 830 *Theory of Stochastic Processes*, but require less mathematical theory as preparation. Both MUSC and CofC are located in downtown Charleston.	The MUSC program is a full-time doctoral program that specializes in Biostatistics within a medical setting and focuses on applications of statistics to the biological and medical sciences. The CofC program offers a general mathematics program with a computational component, attracts students interested in statistics with an emphasis on theory and training in the main statistics computation tools, and supports completion of the degree on a part-time basis. Please see the list preceding this table for more details and additional features that make our program unique in South Carolina.
Ph.D. in Mathematics 60 credits including a minimum of 12 credits of dissertation	USC	Shared goals to train researchers, college teachers, and industry and laboratory professional. USC has an option for computational mathematics USC has an option for Master's entrance	USC has a large doctoral program that draws students from a regional, national, and international applicant pool. The USC program offers most of its courses during daytime (while a part-time option is possible, part-time students are not a significant focus of this program.) The CofC program is a small doctoral program that primarily targets local students, has restricted entrance to individuals with MS-level preparation, and anticipates most of its students to choose the

			part-time option. The CofC program has three-year full-time and five-year part-time program duration, and requires a computational component that is embedded in both pure and applied dissertation research areas. Please see the list preceding this table for more details and additional features that make our program unique in South Carolina.
Ph.D. in Mathematical Sciences 45 credits	Clemson	At least 18 hours of dissertation research Flexible curriculum	Clemson has a large doctoral program that reflects Clemson's status as an R1 university, attracts students from a national and international applicant pool, and is mostly a daytime program. The CofC program is a small doctoral program that is designed to thrive in a liberal arts environment with undergraduate focus, primarily targets local students, and has restricted entrance to individuals with MS-level preparation. The CofC program anticipates most of its students to choose the part-time option and has three-year full-time and five-year part-time program duration. The CofC Mathematics department has research strengths in several areas that are complementary to Clemson's faculty research interests. Such areas include integrable systems and nonlinear waves, mathematical physics and infinite- dimensional Lie algebra, category theory, geometry and topology, logic and nonstandard analysis, information retrieval, and mathematical linguistics. Please see the list preceding this table for more details and additional features that make our program unique in South Carolina.

Table G: Comparison of the *Ph.D. program in Mathematics with Computation* with similar programs in South Carolina.

Faculty

Position	Prospective Courses	Academic Degrees & Coursework	Other Qualifications & Comments
Mathematics Professor, full-time	MATH 604 Algebra II, 3 credit hours (G) MATH 803 Algebra III, 3 credit hours (G)	Doctor of Philosophy (Mathematics), 2006, UNIV ILLINOIS URBANA-CHAMPAIGN	Mathematical physics, integrable systems, differential equations.

	MATH 880 Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)		
Mathematics Professor, full-time	MATH 623 Partial Differential Equations II, 3 credit hours (G) Math 624 Dynamical Systems, 3 credit hours (G) MATH 823 Partial Differential Equations III, 3 credit hours (G) Math 824 Advanced Dynamical Systems, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Applied Mathematics), 1994, UNIVERSITY OF ARIZONA	Integrable systems, nonlinear waves, dynamical systems, geometric evolution equations.
Mathematics Assistant Professor, full-time	Math 604 Algebra II, 3 credit hours (G) Math 803 Algebra III, 3 credit hours (G) Math 880 Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 2016, UNIVERSITY OF OREGON	Representation theory, and its interactions with combinatorics, low dimensional topology, and category theory.
Mathematics Assistant Professor, full-time	MATH 630 Theory of Probability, 3 credit hours (G) Math 880 Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 2015, UNIVERSITY OF OTTAWA	Probability, Ergodic theory, Geometric group theory, Graph theory, Combinatorics.
Mathematics Professor, full-time	MATH 612 Real Analysis II, 3 credit hours (G) MATH 811 Functional Analysis, 3 credit hours (G) MATH 623 Partial Differential Equations II, 3 credit hours (G) MATH 823 Partial Differential Equations III, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1992, DUKE UNIVERSITY	Differential Geometry, Partial Differential Equations: Evolution Equations, Integrable Systems, Exterior Differential Systems.
Mathematics Professor, full-time	MATH 612 Real Analysis II, 3 credit hours (G) MATH 811 Functional Analysis, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1992, UNIV WISCONSIN - MADISON	Mathematical logic, nonstandard analysis, set theory, model theory
Mathematics Professor, full-time	MATH 604 Algebra II, 3 credit hours (G) MATH 803 Algebra III, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G)	Doctor of Philosophy (Mathematics), 1994, RUTGERS UNIV	Representation theory, free field theory, vertex operators, conformal field theory

	MATH 999 Doctoral Dissertation, 1-9 credit hours (G)		
Mathematics Associate Professor, full-time	MATH 630 Theory of Probability, 3 credit hours (G) MATH 830 Theory of Stochastic Processes, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Statistics), 2009, PENNSYLVANIA STATE UNIV	High-dimensional data analysis, semi-parametric methods, robust modeling, variable selection
Mathematics Professor, full-time	MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1995, BOSTON UNIVERSITY	Algebraic analysis, mathematical physics
Mathematics Assistant Professor, full-time	MATH 645 Numerical Analysis II, 3 credit hours (G) MATH 845 Advanced Scientific Computing, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (US Equiv. PhD in Mathematics), 2009, INDIAN INSTIT. OF TECH., DELHI	Numerical analysis and discretization of ordinary and partial differential equations
Mathematics Professor, full-time	MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-12 credit hours (G)	Doctor of Philosophy (Mathematics), 1991, UNIV WISCONSIN - MADISON	Approximation theory, multivariate interpolation
Mathematics Professor, full-time	MATH 623 Partial Differential Equations II, 3 credit hours (G) Math 624 Dynamical Systems, 3 credit hours (G) MATH 823 Partial Differential Equations III, 3 credit hours (G) Math 824 Advanced Dynamical Systems, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (US Equiv Ph.D. in Physics), 2000, UNIV MONTREAL Including the following coursework: MATH 6608 Algebra I (3), MATH 3135 Lebesgue Integral (3), MATH 3362 Differential Geometry (3), MATH 2625 Rings and Fields (3), MATH 6435 Equations from Math Physics (3), PHY 3080 Appl's of Groups in Physics (3), PHY 6812 Field Theory (3)	Nonlinear waves, integrable systems, models of elastic materials, flame propagation, fluids
Mathematics Professor, full-time	MATH 645 Numerical Analysis II, 3 credit hours (G) MATH 845 Advanced Scientific Computing, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Operations Research - CSC (with Minor in Mathematics)), 2002, NORTH CAROLINA STATE UNIV	Information retrieval, numerical linear algebra, optimization
Mathematics Professor, full-time	MATH 645 Numerical Analysis II, 3 credit hours (G) MATH 845 Advanced Scientific Computing, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1986, NEW YORK UNIV	Nonlinear wave phenomena, scientific computing

Mathematics Professor, full-time	MATH 630 Theory of Probability, 3 credit hours (G) MATH 830 Theory of Stochastic Processes, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 2006, INDIANA UNIV - MAIN (001324)	Statistics, nonparametric estimation
Mathematics Assistant Professor, full-time	MATH 612 Real Analysis II, 3 credit hours (G) MATH 811 Functional Analysis, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 2013, NORTH CAROLINA STATE UNIV	Functional analysis, differential and difference equations, dynamical systems
Mathematics Professor, full-time	MATH 612 Real Analysis II, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1979, PENNSYLVANIA STATE UNIV	Mathematical logic, set theory
Mathematics Professor, full-time	Math 624 Dynamical Systems, 3 credit hours (G) Math 824 Advanced Dynamical Systems, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Applied and Computational Mathematics), 2003, PRINCETON UNIV	Dynamical systems, probability, biology and linguistics applications
Mathematics Professor, full-time	MATH 630 Theory of Probability, 3 credit hours (G) MATH 830 Theory of Stochastic Processes, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Statistics), 2007, UNIVERSITY OF GEORGIA	Dimension reduction methods, applied time series, nonparametric methods, statistics applications to finance and econometric
Mathematics Assistant Professor, full-time	MATH 645 Numerical Analysis II, 3 credit hours (G) MATH 845 Advanced Scientific Computing, 3 credit hours (G) Math 624 Dynamical Systems, 3 credit hours (G) Math 824 Advanced Dynamical Systems, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 2017, UNIV OF HOUSTON	Computational and theoretical neuroscience; nonlinear dynamics, control theory, and stochastic processes; Reduced models and parallel computing
Mathematics Associate Professor, full-time	MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 2000, UNIV OF CHICAGO	Geometry and topology of hyperbolic 3-manifolds

Mathematics Professor, full-time	MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1991, UNC CHAPEL HILL	Low-dimensional topology
Mathematics Associate Professor, full-time	MATH 604 Algebra II, 3 credit hours (G) MATH 803 Algebra III, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1991, RUSSIAN ACADEMY OF SCIENCES, NOVOSIBIRSK	Lie algebras, non-associative algebras
Mathematics Associate Professor, full-time	MATH 612 Real Analysis II, 3 credit hours (G) MATH 811 Functional Analysis, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (US Equiv. Ph.D.in Mathematics), 1999, UNIVERSITE DE BOURGOGNE	Asymptotic analysis, orthogonal polynomials, integrable systems
Mathematics Assistant Professor, full-time	MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Applied Statistics), 2021, UNIVERSITY OF ALABAMA	Computational statistics, machine learning, finite mixture modeling, model-based cluster analysis
Mathematics Senior Instructor, full-time	MATH 630 Theory of Probability, 3 credit hours (G) MATH 830 Theory of Stochastic Processes, 3 credit hours (G) MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Statistics), 1995, UNIV CALIF-BERKELEY	Statistics, probability, stochastic processes, statistical learning, data science, predictive analytics, knowledge discovery, data mining
Mathematics Professor, full-time	MATH 880, Advanced Special Topics, 3 credit hours (G) MATH 999 Doctoral Dissertation, 1-9 credit hours (G)	Doctor of Philosophy (Mathematics), 1988, OKLAHOMA ST UNIV - MAIN CAMPUS	Number theory, p-adic analysis

Table H: Graduate faculty roster with qualifications and anticipated involvement in the program.

Faculty, Staff, and Administrative Personnel
Discuss the Faculty, Staff, and Administrative Personnel needs of the program.

More details and justification of the following narrative are provided in Table I below.

Faculty.

Graduate faculty who supervises PhD students and/or teach Ph.D.-level courses will be provided with some teaching releases, support for professional travel, summer research stipends, and release time or stipends for curriculum development.

The mathematics department has a relatively large body of 28 doctoral faculty members, with a broad representation of research areas. As noted by the external M.S. program reviewers and confirmed in Dr. Cenzer's evaluation report, the research output of the faculty compares favorably *to peer or aspirational*

institutions. The latter include other small PhD programs; for example, the math department faculty has produced 205 publications reviewed on MathSciNet in the ten-year period 2011-2021, while Drexel University has 286, Virginia Commonwealth has 193, UNC Wilmington has 84, and Bryn Mawr has 69 listed publications. In addition, the mathematics department also has several strong research groups and *there is a good deal of intersection between several of the research groups*. This will allow sharing the burden of assembling and organizing integrated research teams and create opportunities for team-taught doctoral courses and co-advising of doctoral students.

Given the program's small size and research focus, and the fact that the core sequences make use of existing advanced master-level courses, we anticipate a small number of doctoral-level courses being taught at any given time. The resulting modest increase in FTE need can be covered by the new teaching assistants and adjunct hiring without requiring new faculty lines. Two teaching assistants (doctoral students with master's degree) will each teach one course per semester, offsetting four lower-level course releases for faculty involved in the doctoral program. Adjunct faculty will be hired to teach up to four additional 100-level courses that graduate faculty would have taught.

Administrators.

The current team of graduate program directors will take on additional duties for managing the doctoral program. A dedicated committee of graduate faculty (Graduate Steering Committee) will help with activities specific to the doctoral program, including, e.g., student admission, writing qualifiers and comprehensive examinations.

Staff.

Currently the mathematics department has two full-time administrative staff and one student worker. The small increase in administrative tasks related to the new program will not require hiring of new administrative staff.

YEAR	**NEW**		**EXISTING**		**TOTAL**	
	Headcount	FTE	Headcount	FTE	Headcount	FTE
Faculty. Two teaching assistants (TAs) will each teach one course per semester on any given year. We estimate we will need adjuncts to teach one additional course in Year 2, two additional courses in Year 3, three additional courses in Year 4, and four additional courses in Year 5, in order to account for theses mentoring course releases: an increase by one per year until a steady state of 1FTE.						
2023-2024	2	1/2			1	1/2
2024-2025	3	5/8			1	5/8
2025-2026	3	3/4			1	3/4
2026-2027	4	7/8			1	7/8
2027-2028	4	1			1	1

Staff. We estimate one quarter one administrative assistant FTE will to be dedicated to the proposed program.						
2023-2024			1	1/4	2	1/4
2024-2025			1	1/4	3	1/4
2025-2026			1	1/4	3	1/4
2026-2027			1	1/4	4	1/4
2027-2028			1	1/4	4	1/4
Administration. The additional duties of managing the proposed program are expected to be incorporated into the duties of the graduate program director, given its small size. We estimate a quarter of the program director release time (currently 1/4 FTE) for managing the current graduate program will be devoted to the proposed program.						
2023-2024			1	1/16	1	1/16
2024-2025			1	1/16	1	1/16
2025-2026			1	1/16	1	1/16
2026-2027			1	1/16	1	1/16
2027-2028			1	1/16	1	1/16

Table I: Number and full-time equivalent of program faculty, administrators, and staff.

Resources

Library and Learning Resources

Explain how current library/learning collections, databases, resources, and services specific to the discipline, including those provided by PASCAL, can support the proposed program. Identify additional library resources needed.

The College of Charleston libraries are structured around one main library, the Marlene and Nathan Addlestone Library, with smaller, more specialized libraries that support the diverse teaching and research needs of the institution. The Addlestone Library is the region's top research library: it encompasses 140,000 square feet, accommodates one million volumes, seats 1,600 patrons, offers 20 study group rooms, and maintains 150 computers. The facility was designed to accommodate the technological needs of a contemporary academic library. The computer workstations are equipped with several web browsers, a suite of Microsoft Office software, statistical software packages, and other standard computer applications. These computers are networked to five high-capacity laser printers; one color printer is also available. In addition to 90 desktop computers, students may borrow one of 60 laptops equipped with wireless internet hardware and software. Audio-visual equipment and iMac computers with video editing capabilities are also available. Wireless access is available throughout the library and on Rivers Green.

The library's collection consists of over 1.6 million cataloged monograph titles, over 170,000 journals, over 275,000 media titles and almost 400 databases. Inclusive within these numbers, the physical holdings include 595,572 print monographic titles, 285 print journal titles, and 13,587 physical media items. The

electronic holdings include 1,146,682 electronic monographic titles, 170,959 electronic journals, and 264,652 streaming media items. All faculty and students with a valid College of Charleston account may access these electronic resources from anywhere in the world.

The library is a member of the Partnership among South Carolina Academic Libraries (PASCAL), a consortium of the state's academic libraries together with their parent institutions and state agency partners. PASCAL fosters cooperation on a broad range of issues such as shared licensing of electronic resources (including unlimited access to over 300,000 e-book titles from major publishers and university presses) and universal borrowing. Traditional Interlibrary Loan (ILL) world-wide resource sharing is available through OCLC.

The Addlestone Library completed a major renovation project in the summer of 2014, adding 200 seats for students, new outlets for charging laptops, tablets and other mobile devices, and a new high-tech lecture room that doubles as added study space for students.

In addition to material and technology resources, the libraries employ 25 tenure-track faculty librarians. Librarian instruction and assistance in research and digital scholarship is available for faculty and students. In addition, the Ask Us service provides basic point of need instruction and assistance in research and computing, both online and in person, through a combination of librarians, library staff, information technology professionals, and student employees.

Program-specific resources: assessment and needs

The current quantitative count of the College of Charleston Libraries' holdings in the subject area of mathematics is 13,162 print monographs and 18,805 eBooks. The library also holds 565 print and electronic journal titles in the field of mathematics.

According to the Association of College and Research Libraries (ACRL) (2018) , "libraries are encouraged to use existing institutional peer groups, where available, for comparisons." While it is difficult to compare the collection of an entire subject area from one institution to another, our reviewer compared the mathematics holdings of the College of Charleston Libraries with both a select list of recommended academic titles in the field as well as the holdings of Bryn Mawr College, whose doctoral program has similar scope and size as proposed program.

The select list of titles were recommended by Choice magazine as Outstanding Academic Titles in the subject area of mathematics. Choice is published by ACRL and is a well-known quality resource for book selection in academic libraries.

Currently, the College of Charleston Libraries holds 77% of the titles, either in print or as an eBook, recommended by Choice in their Outstanding Academic Titles series. Comparatively, Bryn Mawr (last surveyed in 2018) owned only 72.7%.

Access to quality journal titles is essential to any academic research, but especially that of a doctoral program. Based on our 2018 assessment, the College of Charleston Libraries currently has access to 18 out of 22 titles listed by librarians at Bryn Mawr College as core journals for the subject area of Mathematics. According to SCImago Journal and Country Rank's (2020) ranking of academic journals in the field of Mathematics, the College of Charleston has electronic subscriptions to 18 of the top 20

journals in the Mathematics subject area. The following lists the journals held by CofC and includes the coverage held in both electronic and print of each (if applicable):

- Journal of the American Mathematical Society (1988-present)
- Molecular Systems Biology (Open Access) (2005-present)
- Publications Mathématiques (1997-present)
- Annals of Mathematics (1988-present in electronic; 1985-2015 in print; 1966-1984 in
- microfilm)
- Journal of Statistical Software (Open Access) (1997-present)
- Journal of Royal Statistical Society, Series B: Statistical Methodology
- (1997-present)
- Annals of Statistics (1973-4 years ago in electronic; 1973-1995 in print)
- Inventiones Mathematicae (1997-present)
- Wiley Interdisciplinary Reviews Computational Molecular Science (2011-present)
- Journal of Business and Economic Statistics (1983-6 years ago)
- Journal of the American Statistical Association (1992-present in electronic;
- 1962-2015 in print)
- SIAM Review (1959-present in electronic; 1983-2014 in print)
- Journal of Differential Geometry (1967-2017; 1969-2014 in print)
- Acta Mathematica (Open Access after 2016) (1882-2016)
- Structural Equation Modeling (1997-present)
- Geometric and Functional Analysis (1997-present)
- American Journal of Mathematics (1878-present; 2001-2004 in print)
- IEEE Transactions on Pattern Analysis and Machine Intelligence (1979-present)

Based on previous assessments performed by the College of Charleston librarians in 2014 and 2018, as well a recent evaluation conducted by the Collection Development Librarian in 2021, the College of Charleston Libraries' print holdings in the subject area of mathematics are sufficient to support the current bachelor's and master's programs offered by the college. In order to enhance the collection further to support a doctoral program, it is suggested that the college actively attempt to collect all materials noted by Choice as Outstanding Academic Titles in mathematics.

The current firm order budget for the 2022-2023 fiscal year is sufficient to cover the cost of new, specialized materials to be purchased in support of a small doctoral program in mathematics, provided that the Mathematics faculty liaison selects these materials appropriately. However, additional permanent funding should be provided to the library in future years to continue to support the department and program. It is the recommendation of the College Libraries to eventually purchase new journals in support of the program, pending funding.

We also anticipate the need to increase holdings specific to the computational component of the program. While most documentation for symbolic and numerical computation is now freely available as open-source resources, we will work with the library to increase resources, including journals and monographs, in this area.

Student Support Services

Explain how current academic support services will support the proposed program. Identify new services needed and provide any estimated costs associated with these services.

In addition to the library and learning resources, we list below the academic support services that are most pertinent to the proposed program.

- **Information Technology:** This office provides additional computing resources to students and faculty, technical support for video capturing and remote delivery of lectures, and support with software and hardware. A dedicated student help desk is available via email or telephone.

- **Office of Research and Grants Administration (ORGA):** ORGA is the central resource for information and assistance regarding major government agencies, foundations, and corporations that support research and scholarship. Dedicated staff is available to assist faculty, students, and administrators in identifying extramural funding sources, developing funding and completing proposals, developing narratives and budgets, ensuring compliance with federal and state regulations, negotiating grant awards and contracts, and administering funded projects.

- **Teaching and Learning Team (TLT)**: supports, develops and educates in the integration of educational technology into pedagogy, by providing resources, support, consultations, workshops, and other holistic professional development opportunities for faculty to enhance teaching and learning. TLT maintains a Tutorials blog with information on a plethora of educational technology tools.

- **Office of Institutional Diversity (OID):** The Office of Institutional Diversity offers education, training, resources, and support for all students, faculty, and staff. OID fosters and advocates for a globally diverse campus at the College of Charleston.

- **Center for Disability Services:** The College of Charleston is committed to ensuring that all programs and services are accessible to a diverse student population. The center provides reasonable and effective accommodations to facilitate student learning, and offers educational opportunities to students, faculty, and staff that enhance understanding of a broad spectrum of disabilities and promotes an environment of institutional respect for disabilities.

- **Career Center:** The Career Center is a multifaceted resource center with a goal of educating and assisting students in preparing for transition to the dynamic work environment.

- **Cougar Card Services:** All students will receive a Cougar Card. This official College of Charleston identification card connects students to all campus resources.

- **Dining Services:** A variety of dining options located throughout the College of Charleston campus are available to students.

- **Student Health Services:** Student Health Services provide quality primary health care in an ambulatory setting. The center provides students with access to early diagnosis and treatment of the conditions that they have or develop while in attendance at the College, and promotes awareness of the importance of regular health maintenance.

- **Resource Coordinator:** The Resource Coordinator acts as an impartial party who gives guidance and/or explanations of policies and procedures for employees, faculty and students who encounter

problems arising from the operation of the college and who request assistance in identifying the proper person, office, policy, or procedure that can best address their particular situation.

- **Attorney Assistance Program:** Up to one hour of legal services are available on a pro bono basis to students who face a variety of financial or legal difficulties.

- **Counseling and Substance Abuse Services:** The mission of the College's Counseling and Substance Abuse Services is to increase student psychological resilience and personal growth to support persistence and success in school.

- **Office of Victims Services:** Services are available to College of Charleston students regardless of whether the crime occurs on campus or the student elects to file an official police report or not. Certified victim assistance specialists provide support for both short and long-term issues associated with trauma and victimization issues, and help students address issues related to the crime and its impact on the college experience.

Physical Resources/Facilities
Identify the physical facilities needed to support the program and the institution's plan for meeting the requirements.

The Department of Mathematics is housed on the third floor of the Robert Scott Small building, where most offices and meeting spaces are located, including a large office for graduate students, two study/research rooms and one conference room. Dedicated mathematics classrooms are located in Maybank Hall, directly across from the Robert Scott Small building.

The following rooms in particular have special facilities, beyond the equipment that is standard in our classrooms: a video projector, instructor computer, document camera, laptop connection, along with blackboards usable simultaneously with the projector screens. They will support various program's activities including recording and live streaming of lectures and research meetings (virtual and on-site).

MYBK 200 Computer Classroom. This room has thirty student computers (macOS) on large, shared desks with plenty of room for working and collaborating side-by-side in small groups. It also has a system for both audio-video capture of lectures for later viewing and live streaming of lectures, with several cameras and microphones so that remote viewers can hear and see not only the instructor but also the students in the room, along with direct computer-screen capture.

RSS 353 Conference Room. This room is equipped with a large (90") video display that can be connected to computers either by HDMI or wirelessly, along with blackboards on two walls. It seats up to about fifteen for meetings that use only the screen for presentation, and about ten when the boards are also in use. Thus, it is well-suited for seminars, working groups, reading courses, and advanced graduate classes with small enrollments.

RSS 201 Center for Computational and Applied Research in Mathematics. This recently established center, directed by Dr. Mukesh Kumar, will provide additional facilities and computing support, as well as opportunities for interdisciplinary interactions to students and faculty in the program.

Since the proposed program will keep offering courses in the late afternoon and evenings, there is adequate classroom space. We are well-equipped for both teaching and mathematical research and we can easily accommodate the predicted small number of students.

We plan to designate one of the Mathematics department offices for the use of full-time doctoral students. We already have an adequate number of rooms that can be used for research purposes. We do not expect need of additional space in the first five years. Should more meeting space be needed because of the increase number of research team, we will work with the School of Science and Mathematics Dean to located additional research meeting space.

No modification of existing facilities is required. The number of students will be very small, with no more than 3 full-time students, and is not projected to grow.

The College operates and maintains its physical facilities in a manner that supports its strategic plan, academic programs, support services, and other mission-related activities by completing or using routine maintenance, repairs, grounds maintenance, energy management, custodial services, engineering, construction, space management, and capital planning.

Equipment
Identify new instructional equipment needed for the proposed program.

There is no additional equipment needed that is specific to the proposed program. The department has adequate access to computer facilities and departmental laptops. The department has site licenses for Mathematica and MatLab for faculty and students, and supports a wide range of free special purpose mathematical software, such as LaTeX, Pari, Scientific Python, Octave, Julia, and R.

The following is especially relevant to the program, given its emphasis on computation.

CofC Computer Cluster Access. Students and faculty the Department of Mathematics at the College of Charleston have access to two resources for cluster computing.

The first is the new High Performance Computing Linux cluster installed at the College in Spring 2019. This is available for use by faculty and by students with endorsement or sponsorship by their faculty/staff mentor. It has a nominal peak performance of 51 TeraFLOPS, provided by 10 standard compute nodes each with two 20-core processors and 2 GPU-containing nodes with INVIDIA Tesla V100 16GB GPU. For more details, see https://hpc-cofc.gitbook.io/docs

The second is access to computer time on the NSFs XSEDE network of HPC systems. Use of these resources is supported by staff lead by Senior HPC System Administrator and Facilitator Berhane Temelso, a researcher in computational chemistry.

Impact on Existing Programs
Will the proposed program impact existing degree programs or services at the institution (e.g., course offerings or enrollment)? If yes, explain.

☒Yes

☐No

The proposed program will benefit our master's program in Mathematical Sciences by strengthening the curricular offerings. The second-semester courses in the master's program (Math 604, Math 612, Math 623, Math 624, Math 630, Math 645) are the first-semester courses of the PhD core sequences.

A typical PhD Program of Study will have no more than 9 credits (3 first-semester core courses) overlapping with the existing master's program or a maximum of 21% of the PhD program credits. Note: This appears to be significantly lower than many doctoral programs, including USC and Clemson. The overlap is, at most, in three first-semester courses (which are taken by few MS students). For many doctoral students, the overlap will be 14% or 8%, if they transfer one or two of the 600-level courses from other institutions.

Financial Support

ESTIMATED COSTS BY YEAR						
CATEGORY	1ST	2ND	3RD	4TH	5TH	TOTALS
Program Administration						
Faculty Salaries	9,000	15,000	18,000	21,000	24,000	87,000
Graduate Assistants	44,000	44,000	44,000	44,000	44,000	220,000
Clerical/Support Personnel						
Supplies and Materials						
Library Resources	3,500	3,500	2,500	2,500	2,000	14,000
Equipment						
Facilities						
Other (Identify)						
TOTALS	56,500	62,500	64,500	67,500	70,000	321,000
SOURCES OF FINANCING BY YEAR						
Tuition Funding	23,197	32,202	35661	42,935	46394	180,389
Program-Specific Fees						
State Funding						
Reallocation of Existing Funds	27,000	27,000	27,000	27,000	27,000	135,000
Federal Funding						
Other Funding	11,200	11,200	11,200	11,200	11,200	56,000
TOTALS	61,397	70,402	73,861	81,135	84,594	371,389

Table J: Program costs and sources of financing (5-year estimate).

Budget Justification

Provide an explanation for all costs and sources of financing identified in the Financial Support table. Include an analysis of cost-effectiveness and return on investment and address any impacts to tuition, other programs, services, facilities, and the institution overall.

Costs.

Faculty Salaries. We estimate the need of three course releases in Year 1, five in Year 2 and increasing by one per year until a steady state of 8 course releases is reached in Year 5. The current adjunct rate is $3000 per three credit hour course.

Graduate Assistantships. Two new doctoral teaching assistantship at $22,000/year each.

Library Resources. The initially higher allocation accounts for filling gaps in areas of symbolic computation and computational mathematics, as well topological data analysis and functional analysis (research areas of the two most recent hires), all critical areas to the Ph.D. program in Mathematics with Computation. Steady state allocation will allow increase in recommended journal subscription.

Sources of financing.

Tuition Funding. The estimate is based on the enrollment estimates provided in Table C, and on the assumption of one out-of-state student and the rest being in-state students. The tuition revenue is conservatively computed as one eighth of the credit hours generated each year from Table C. These amount to 33 credit hours the first year: 29 in-state and 4 out-of-state, 45 credit hours the second year: 39 in-state and 6 out-of-state, 51 credit hours the third year: 45 in-state and 6 out-of-state, 60 credit hours the fourth year: 52 in-state and 8 out-of-state, and 66 credit hours the fifth year: 58 in-state and 8 out-of-state; using the in-state rate of $576.50 per credit hour and the out-of-state rate of $1619.67 per credit hour.

Reallocation of Existing Funds. Two graduate teaching assistantships at $13,500 each will be reallocated from the graduate teaching assistantship pool by Academic Affair/Graduate School.

Other Funding. The two full-time graduate Teaching Assistants in the program will teach four courses per year, offsetting $3000 per course.

Evaluation and Assessment

Program Mission Statement: The PhD in Mathematics with Computation will serve the Charleston community by developing the modern PhD mathematician. Graduates will be experts in both mathematical theory and the use of modern computational software in their area of research. They will be uniquely positioned for scientific opportunities in government, in industry and as innovative leaders in higher education.

Program Goals:

1. Offer a doctoral degree in *Mathematics with Computation* to a select group of highly talented individuals who are either bound or drawn to Charleston for a variety of reasons.
2. Offer flexible, individual-centered instruction and research training, whether focused on a specific mathematical area or centered upon broader interdisciplinary studies.
3. Develop broad research training, high level technical abilities, and long-term project skills for individuals interested in employment in the scientific and technical sector (such as industry, laboratories, science policy jobs, and technology start-up companies).

4. Provide doctoral candidates with unique opportunities and extensive support to develop their teaching skills in an environment where excellence in undergraduate instruction is a top priority.
5. Continue and enhance the tradition of nurturing a close-knit group of graduate students and mathematics undergraduates, offering additional opportunities for vertically integrated research in teams, and providing our undergraduate majors with an exceptional learning experience with increased opportunities for one-to-one attention and small group learning.
6. Build upon the strong research qualifications and achievements of several groups and individual faculty members in the Mathematics Department.
7. Allow graduates from other mathematics programs to study under the tutelage of our internationally recognized research faculty.

The curricular map below shows how the learning outcomes are tied to the program requirements (I – Introduce, R – Reinforce, D – Demonstrate)

	Elements/SLOs	SLO1	SLO2	SLO3	SLO4	SLO5
Core (1st semester)	Math 604	I/R	I	I		I
	Math 612	I/R	I			I
	Math 623	I/R	I			I
	Math 624	I/R	I	I		I
	Math 630	I/R	I			I
	Math 645	I/R	I	I/R		I
Core (2nd semester)	Math 803	I/R	I/R		I	I/R
	Math 811	I/R	I/R		I	I/R
	Math 823	I/R	I/R	I	I	I/R
	Math 824	I/R	I/R	I	I	I/R
	Math 830	I/R	I/R	I/R	I	I/R
	Math 845	I/R	I/R	I/R	I	I/R
Elective	Math 880	R	R		I	I/R
Examinations	Comprehensive Examinations	R/D	I			D
	Doctoral Proposal Oral Examination	R	R/D		I	
	Doctoral Defense	D	D	D	D	D
Thesis	Dissertation	R/D	D	R/D	R/D	R/D

Table K: Curriculum Map

The Student Learning Outcomes (SLOs) will be assessed using the methods listed below and will be documented each year as a part of the Institutional Effectiveness Assessment process.

Student Learning Outcomes Aligned to Program Objectives	Methods of Assessment
1. Students will demonstrate advanced knowledge and application of several of the following core areas: Algebra, Analysis, Differential Equations/Dynamical Systems, Scientific Computing and Numerical Analysis, and Probability and Statistics.	**Measure 1.1:** The final exams/final projects of Math 803, Math 811, Math 823, Math 824, Math 830, and Math 845 will be used to assess advanced knowledge and understanding of core areas. The Graduate Steering Committee will utilize appropriate scoring rubrics, including scores for individual questions as well as an overall score. It is expected that 85% of students will be rated acceptable (i.e. correctly answering at least 80% of the exam questions) or above on this category. Individual question scores will be used to identify any area in need of improvement. **Measure 1.2:** The Comprehensive Examinations will be evaluated by a committee of graduate faculty in collaboration with the Graduate Steering Committee. Appropriate scoring rubrics will be utilized. It is expected that 80% of students will be rated acceptable for continuing the program.
2. Students will be able to identify and conduct original research and scholarship, and communicate effectively the results of their research.	**Measure 2.1:** The Dissertation Proposal Oral (DPO) Examination will be assessed for each doctoral candidate by the DPO Examination Committee, using an appropriate scoring rubric. It is expected that 85% of the students will be rated acceptable for continuing the program. **Measure 2.2:** The doctoral dissertation will be assessed for each doctoral candidate by the Dissertation Committee, using an appropriate scoring rubric. It is expected that 90% of the students will be rated acceptable or above on this category.
3. Students will demonstrate the ability to make integral use of the available computational tools to advance their area of research, through experimental mathematics, computer-assisted proofs, development of numerical or statistical codes yielding new mathematical data, and/or other	**Measure 3.1:** All homework and projects requiring students' use of computational software will be assessed by the Graduate Steering committee for all PhD students in the following courses: Math 604, Math 823, Math 824, Math 830, Math 845. Appropriate scoring rubrics will be utilized. It is expected that 85% of the student will be rated acceptable or above on this category. **Measure 3.2:** The computational component of the doctoral dissertation will be assessed for each doctoral candidate by the Dissertation Committee, using an appropriate scoring rubric. It is expected that 90% of the students will be rated acceptable or above on this category

computationally intensive methodologies.	
4. Students will demonstrate their ability to contribute to advancing research in mathematics and related fields.	**Measure 4.1:** The doctoral dissertation will be assessed for each doctoral candidate by the Dissertation Committee, using an appropriate scoring rubric. It is expected that 90% of the students will be rated acceptable or above on this category. **Measure 4.2:** Research publications and presentations of graduates of the program will be tracked. Sources of data collection could include email communication, Google scholar, AMS Mathematical Reviews, and other common repositories of publications in the mathematical sciences. It is expected that 90% of students will have published at least one article and given research presentations within three years of graduation.
5. Graduates will be prepared for employment or further research training in mathematics.	**Measure 5.1:** Exit interviews and alumni surveys one year post graduation will be used to determine what fraction have an appropriate employment (including promotion from existing position) or post-doctoral appointment within one year from graduation. It is expected that 80% of graduates will report a positive outcome. **Measure 5.2:** Alumni surveys conducted three years post graduation. It is expected that 90% of graduates will be employed in a satisfactory position in industry, research laboratories, or higher education.

Table L: Program Student Learning Outcomes and Measures.

Explain how the proposed program, including all program objectives, will be evaluated, along with plans to track employment. Describe how assessment data will be used.

The College of Charleston's institutional effectiveness (IE) assessment model engages broad-based participation and encompasses several key faculty, staff, and administrator roles. The IE assessment model is an ongoing, broad-based process and involves collaborations between assessment coordinators, the Dean's Assessment Committees (DACs) members at the school level, the Administrative Assessment Committees (AACs) members at the division level, the chairs of the DACs and AACs who comprise the Institutional Assessment Committee (IAC), the provost or executive vice presidents, and the president.

Assessment coordinators (faculty and staff members) work collaboratively with colleagues in their programs or units to develop an assessment plan and report and coordinate their programs or units ongoing assessment processes. The DACs are school-level assessment committees that exist for each school or college. The DAC consists of faculty across the varying disciplines. These committee

members serve as mentors and work collaboratively with their programs to assist the assessment coordinators in their assessment efforts and to provide a review of the quality of the assessment reports based on established criteria provided in the institutional assessment rubrics. The rubrics replaced reviewer-rating scales that were in effect from 2011-2012 to 2014-2015. The DAC members use rubrics to focus discussion on the rubric indicators for increasing quality of assessment plans and results. The chair of each DAC serves on the IAC.

The IAC is an institutional-level committee that consists of the DAC and AAC chairs. The IAC ensures the quality of the reviews conducted by the DAC and AAC through its oversight of the review process. Annually, each member of the IAC presents a DAC or AAC report about the quality of the results and plans. It contains program or unit examples and use of results to make improvements. Committee rosters and meeting minutes are archived at the Office for Institutional Effectiveness and Strategic Planning (OIEP) website. The executive vice presidents (EVPs) and the president review a random sample of completed rubrics for academic programs and administrative units and provide additional feedback, if necessary. The Office for Institutional Effectiveness and Strategic Planning (OIEP) serves as a support office for assessment coordinators, AAC members, DAC members, IAC members, EVPs, and the president.

Assessment Process and Components of Assessment Reports: The College follows an annual assessment cycle with plans due in early fall and results reports due at the end of the spring term. Assessment coordinators (faculty and staff members in each academic program and administrative unit) for each program or unit work with all program faculty or staff members to develop a plan with outcomes consistent with the mission, select and implement measures, analyze results, and plan for improvements based on the results that are then assessed in the subsequent plan. There are two phases of the collaborative process that represent the two parts of an assessment report. Assessment coordinators (1) develop a plan with outcomes and measures and (2) analyze results for each measure and use results to make changes in curriculum, pedagogy, or operations. Coordinators also provide necessary changes in the use of results and assessment summary sections in Compliance Assist.

Broad-based Participation, Periodic Review, and Quality Assurance Process: Broad-based participation is the foundation of the College's IE assessment model. Broad-based participation is characterized by active involvement and contributions of faculty, staff, and administrators who are organized into DACs or AACs. Deans, associate vice presidents, and executive vice presidents oversee the implementation of assessment plans and results in their respective schools or divisions. The president provides institution-wide leadership to the IE assessment process and gives the charge to the IAC.

The assessment coordinators submit the plans and results for review to the assigned DAC or AAC. The assigned DAC or AAC mentor and DAC or AAC chair in each school or division review the quality of the assessment plan and reports based on established criteria defined in the IE assessment rubrics: the assessment plan rubric and the assessment results rubric.

These rubrics are a tool for providing specific feedback and replace a previous feedback instrument in order to improve the quality and increase the rigor of the assessment plans and reports by setting expectations and promoting discussion. The Assessment Plan Rubric and the Assessment Results Rubric enhance the collaborative process to deepen the culture of assessment.

Based on feedback from DAC and AAC, assessment coordinators (faculty and staff members) have the opportunity to revise and improve the quality of plans and reports and resubmit to the assigned committee member and chair, who serves on the IAC. The results and plans go through this iterative review process until the DAC or AAC chair approves the results and plans. The EVPs and the president review a random sample of completed rubrics for programs and administrative units and provide additional feedback, if necessary.

Institutional Support

The OIEP provides customized consultations and conducts workshops for faculty, staff, assessment coordinators, and DAC, AAC, and IAC members to support the annual IE assessment process. The OIEP maintains Compliance Assist, which allows academic programs and administrative units to submit assessment plans and results reports. The OIEP also plans, coordinates, administers, and publishes results from several national and enterprise-level surveys conducted at the College of Charleston.

Institutional Support: The OIEP provides customized consultations and conducts workshops for faculty, staff, assessment coordinators, and DAC, AAC, and IAC members to support the annual IE assessment process. OIEP maintains Compliance Assist, which allows academic programs and administrative units to submit assessment plans and results reports. OIEP also plans, coordinates, administers, and publishes results from several national and enterprise level surveys conducted at the College of Charleston.

Tracking Employment: The program director will track student employment statistics for our graduates at the local, state, national, and international levels. Exit interviews and alumni surveys will be used to gather data. Local employers and the graduate program Industry board will be involved to provide qualitative evaluation.

Use of Results: Closing the Loop

It is the responsibility of the assessment coordinator (graduate program director) to assess all SLOs. The data collected as a part of assessment will be analyzed to see how well the listed student outcomes were achieved. Based on the results, the assessment committee in consultation with the department will develop an “action plan” that includes but is not limited to revisiting the performance level set as well as other programmatic changes. Program assessment will be done on a continuous basis to improve the quality of the Ph.D. in Mathematics with Computation program offered at College of Charleston.

Accreditation and Licensure/Certification

Will the institution seek program-specific accreditation (e.g., CAEP, ABET, NASM, etc.)? If yes, describe the institution’s plans to seek accreditation, including the expected timeline.

☐ Yes

☒ No

Will the proposed program lead to licensure or certification? If yes, identify the licensure or certification.

☐ Yes

☒ No

Explain how the program will prepare students for this licensure or certification.

N/A

If the program is an Educator Preparation Program, does the proposed certification area require national recognition from a Specialized Professional Association (SPA)? If yes, describe the institution's plans to seek national recognition, including the expected timeline.

☐ Yes

☒ No