Computational Mathematical and Statistical Sciences (CMPS)

Chairperson: Anne Clough, Ph.D.
Program Director: Daniel B. Rowe, Ph.D.
Computational Sciences website (https://www.marquette.edu/grad/programs-computational-sciences.php)

Degrees Offered

Master of Science, students are admitted under Plan B (non-thesis option) but Plan A (thesis option) is also offered; Doctor of Philosophy

Program Description

Computational mathematical and statistical sciences (CMPS) is a field of study that emphasizes the discovery, implementation and use of computational tools to solve problems in mathematics and statistics that are both applied and pure. The master's degree program accommodates students whose objectives are either the master's degree or the preparation for doctoral study. The doctoral program is designed for individuals of outstanding ability who show promise as researchers in an interdisciplinary environment.

The diverse research opportunities in our graduate program are enhanced by the research faculty around Marquette's campus in the sciences and engineering and by the Milwaukee area research laboratories and clinics. Consult the Department of Mathematical and Statistical Sciences website for the most current information.

Prerequisites for Admission

Admission to the master's program in computational mathematical and statistical sciences requires an undergraduate degree in mathematics, statistics or a related field such as computer science, engineering or an area of science, with at least a minor (3 courses beyond a full calculus sequence) in mathematics and proficiency in a high-level computer language.

Admission to the doctoral program in computational mathematical and statistical sciences requires (in addition to the prerequisites for master's admission) demonstrated promise for original research.

Application Deadline

To be considered for fall admission, all application requirements must be completed and received in the Graduate School. The priority deadline for review of applications is Jan. 15 for both the master's and doctoral programs. After the priority deadline, applications will be reviewed on a rolling basis.

Application Requirements

Applicants must submit, directly to the Graduate School:

1. A completed online (http://marquette.edu/grad/future_apply.shtml/) application form and fee.
2. Copies of all college/university transcripts except Marquette.
3. Three letters of recommendation addressing the applicant’s academic qualifications for graduate study in the intended program.
4. A statement of purpose outlining relevant work experience or education, career goals, possible areas of interest and reasons for seeking admission to this program.
5. (For international applicants only) a TOEFL score or other acceptable proof of English proficiency.
6. (For doctoral applicants only) English-language publications authored by the applicant, including a master's thesis or essay, if applicable (optional, but strongly recommended).

Optional application requirement for doctoral and all international applicants: GRE scores (General Test only).

Upon admission, final official transcripts from all previously attended colleges/universities, with certified English translations if original language is not English, must be submitted to the Graduate School within the first five weeks of the term of admission or a hold preventing registration for future terms will be placed on the student’s record.

Computational Mathematical and Statistical Sciences Master of Science

A master's student must complete a plan of study prepared in cooperation with an adviser and approved by the Graduate Committee of the Department of Mathematical and Statistical Sciences.

A master's student is admitted to the non-thesis program (Plan B). A formal request to pursue a thesis (Plan A) must be approved by the department's Graduate Committee and the Graduate School.
Thesis Option (Plan A)
All Plan A computational mathematical and statistical sciences master's students must complete a minimum of 24 credit hours of course work (which includes the 15 credit hour core, a 3-credit, adviser-approved COSC course and 6 credit hours of approved electives), 6 thesis credit hours and submit a thesis that must be an original contribution to the student's field of study. A public defense of the thesis is required.

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
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<tbody>
<tr>
<td>MSSC 6000</td>
<td>Scientific Computing</td>
<td>3</td>
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<td>3</td>
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<tr>
<td>An adviser-approved 6000-6899 COSC course</td>
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<td>Approved elective courses, which may include only 1 credit of MSSC 6090</td>
<td>6</td>
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<tr>
<td>MSSC 6999</td>
<td>Master's Thesis</td>
<td>6</td>
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</table>

Total Credit Hours: 30

Essay Option (Plan B)
All Plan B computational mathematical and statistical sciences master's students must complete a minimum of 30 credit hours of course work (which includes the 15 credit hour core; a 3-credit, adviser-approved COSC course and 12 credit hours of approved electives) and submit a non-credit essay that reflects the student's ability to synthesize source materials relating to a particular area of research or professional practice. A public oral presentation of the essay is required.

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<tr>
<td>Approved elective courses, which may include only 1 credit of MSSC 6090</td>
<td>12</td>
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</tbody>
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Total Credit Hours: 30

Computational Mathematical and Statistical Sciences Doctorate
A doctoral student in computational mathematical and statistical sciences must first complete a plan of study, designed to see the student through completion of the comprehensive examination. This plan of study should be prepared in cooperation with an adviser and approved by the Graduate Committee of the Department of Mathematical and Statistical Sciences.

Upon completion of the comprehensive examination, a doctoral student must then complete a program of study designed to see the student through completion of the program. This program of study should be defined, in cooperation with an adviser, on a Doctoral Program Planning Form and approved by the department's Graduate Committee.

The total 57-credit program includes a minimum of 45 credit hours of approved course work beyond the bachelor's degree plus 12 dissertation credits. Students must complete:

- the 15 credit hour core,
- a 3 credit hour adviser-approved COSC course,
- the 2 credit hours of MSSC 6090 Research Methods/Professional Development,
- at least 25 credit hours of electives. Approved programs of study normally include 6 credits of courses outside the department and no more than 12 credit hours in courses at the 5000 level.
- the 12 credit hours of MSSC 8999 Doctoral Dissertation.

Advancement to candidacy for the doctoral degree is considered after successful completion of the comprehensive examination, completion of all course work specified in the Doctoral Program Planning Form and successful completion of the qualifying examination, conducted by the student's doctoral committee. Typically, the doctoral committee also serves as the dissertation committee.
A full-time doctoral student is expected to complete the core courses within the first two years of study, and to take the comprehensive examination at the first opportunity after their completion. A student who enters the program with the necessary core courses is expected to take the comprehensive exam at the first available time it is offered.

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<td>3</td>
</tr>
<tr>
<td>MSSC 6090</td>
<td>Research Methods/Professional Development</td>
<td>2</td>
</tr>
<tr>
<td>MSSC 8899</td>
<td>Doctoral Dissertation</td>
<td>12</td>
</tr>
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</table>

Total Credit Hours: 57

All newly admitted CMPS doctoral students who begin the program without an earned master's degree in an acceptable field are simultaneously enrolled in the CMPS master of science program as a Plan B (Essay Option) student. These students concurrently complete both degrees as part of the doctoral course of study.

Courses

**MSSC 5020. The Teaching of Mathematics. 3 cr. hrs.**

Historical background, problems, curricular materials, and teaching procedures in the various areas of mathematics pertinent to the needs of a secondary school mathematics teacher. In addition, a three-hour time block on one day each week between 8 a.m. and 3 p.m. must be kept free for clinical experience.

**MSSC 5030. Concepts in Geometry and Calculus from an Advanced Standpoint. 3 cr. hrs.**

Topics chosen primarily from geometry and calculus, taught from an advanced standpoint to enrich and deepen the student's understanding. Emphasis on alternative approaches, generalizations, historical contexts and connections with prior mathematical studies.

**MSSC 5040. Concepts in High School Algebra and Number Theory from an Advanced Standpoint. 3 cr. hrs.**

Topics closely related to the high school mathematics curriculum, chosen primarily from algebra and number theory, taught from an advanced standpoint to enrich and deepen the student's understanding. Emphasis on alternative approaches, generalizations, historical contexts and connections with prior mathematical studies.

**MSSC 5120. Abstract Algebra 1. 3 cr. hrs.**

Sets, mappings, operations on sets, relations and partitions. A postulational approach to algebraic systems including semigroups, groups, rings and fields. Homomorphisms of groups and rings, number systems, polynomial rings.

**MSSC 5121. Abstract Algebra 2. 3 cr. hrs.**

A continuation of MSSC 5120 with emphasis on groups, rings, fields and modules.

**MSSC 5200. Intermediate Analysis 1. 3 cr. hrs.**

Limits and continuity, differentiability, Riemann integration. Topology of N-dimensional spaces.

**MSSC 5201. Intermediate Analysis 2. 3 cr. hrs.**

Transformations of N-spaces, line and surface integrals, sequences and series, uniform convergence.

**MSSC 5210. Complex Variables. 3 cr. hrs.**

Complex numbers, analytic functions, differentiation, series expansion, line integrals, singularities and residues.

**MSSC 5310. History of Mathematical Ideas. 3 cr. hrs.**

Topics selected from the following: development of the number system (need for irrational and complex numbers); development of geometry including the effects of the discovery of non-Euclidean geometry; limit concept; need for axiomatic structures; twentieth-century problems. Current mathematics research and place of mathematics in today's world.

**MSSC 5320. Theory of Numbers. 3 cr. hrs.**

Integers, unique factorization theorems, arithmetic functions, theory of congruences, quadratic residues, partition theory.

**MSSC 5420. Foundations of Geometry. 3 cr. hrs.**

Modern postulational development of Euclidean and non-Euclidean geometries.

**MSSC 5450. Topology. 3 cr. hrs.**

Topological spaces, mappings, metric spaces, product and quotient spaces. Separation axioms, compactness, local compactness and connectedness.
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<th>Credits</th>
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<tbody>
<tr>
<td>MSSC 5500</td>
<td>Theory of Differential Equations</td>
<td>3 cr.</td>
<td>Existence and uniqueness theorems, linear and non-linear systems, numerical techniques, stability.</td>
</tr>
<tr>
<td>MSSC 5540</td>
<td>Numerical Analysis</td>
<td>3 cr.</td>
<td>Numerical solution of algebraic and transcendental equations, linear systems and the algebraic eigenvalue problem, interpolation and approximation, numerical integration, difference equations, numerical solution of differential equations and finite difference methods.</td>
</tr>
<tr>
<td>MSSC 5560</td>
<td>Mathematical Modeling and Analysis</td>
<td>3 cr.</td>
<td>Construction and analysis of mathematical models from biological, behavioral and physical sciences.</td>
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<tr>
<td>MSSC 5620</td>
<td>Theory of Optimization</td>
<td>3 cr.</td>
<td>Fundamental theorems describing the solution of linear programs and matrix games. Minimax, duality, saddle point property, simplex and specialized algorithms. Zero sum games, transportation and assignment problems, applications to economics.</td>
</tr>
<tr>
<td>MSSC 5630</td>
<td>Applied Combinatorial Mathematics</td>
<td>3 cr.</td>
<td>Permutations and combinations, recurrence relations, inclusions and exclusion, Polya's theory of counting, graph theory, transport networks, matching theory.</td>
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<tr>
<td>MSSC 5700</td>
<td>Probability</td>
<td>3 cr.</td>
<td>Random variables, distributions, moment generating functions of random variables, various derived probabilistic models and applications.</td>
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<tr>
<td>MSSC 5710</td>
<td>Mathematical Statistics</td>
<td>3 cr.</td>
<td>Sampling theory and distributions, estimation and hypothesis testing, regression, correlation, analysis of variance, non-parametric methods, Bayesian statistics.</td>
</tr>
<tr>
<td>MSSC 5740</td>
<td>Biostatistical Methods and Models</td>
<td>3 cr.</td>
<td>Introduction to the statistics of life science and the use of mathematical models in biology. Data analysis and presentation, regression, analysis of variance, correlation, parameter estimation and curve fitting. Biological sequence analysis, discrete and continuous mathematical models and simulation.</td>
</tr>
<tr>
<td>MSSC 5750</td>
<td>Computational Statistics</td>
<td>3 cr.</td>
<td>Explores computational data analysis, an essential part of modern statistics. Introduces statistical computing including statistical programming. Monte Carlo simulation and parallel computing, smoothing and density estimation, implementing numerical methods in R (e.g., Expectation-Maximization algorithm), fitting models to data, statistical prediction and cross-validation.</td>
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<tr>
<td>MSSC 5780</td>
<td>Regression Analysis</td>
<td>3 cr.</td>
<td>Basic concepts of statistical inference, simple linear regression, multiple linear regression, diagnostic analysis, selecting the best equation, stepwise methods, nonlinear regression, use of statistical software.</td>
</tr>
<tr>
<td>MSSC 5931</td>
<td>Topics in Mathematical or Statistical Sciences</td>
<td>1-3 cr.</td>
<td>Topics selected from one of the various branches of mathematics or statistics. Specific topics to be announced in the Schedule of Classes.</td>
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<tr>
<td>MSSC 6000</td>
<td>Scientific Computing</td>
<td>3 cr.</td>
<td>Foundational methods and techniques of scientific computing in the mathematical and statistical sciences. Covers fundamental computational algorithms aimed toward applications in science and engineering. Students implement algorithms, and visualize and validate their outcomes. Further, students are introduced to and implement best programming practices. Prereq: Calculus course or cons. of instr.; introductory statistics course or cons. of instr.; and programming competency in a high-level language.</td>
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<tr>
<td>MSSC 6010</td>
<td>Computational Probability</td>
<td>3 cr.</td>
<td>A modern course in probability. Foundations of probability for modeling random processes with computational techniques. Topics include counting techniques, probability of events, random variables, distribution functions, probability functions, probability density functions, expectation, moments, moment generating functions, special discrete and continuous distributions, sampling distributions, transformation of variables, prior and posterior distributions, Law of Large Numbers, Central Limit Theorem, the Bayesian paradigm. Numerical and computational methods will be covered throughout topics. Prereq: Three semesters of mathematics beyond calculus and MATH 4720 or equiv.</td>
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</table>
MSSC 6030. Applied Mathematical Analysis. 3 cr. hrs.
Foundational topics in analysis considered from a modeling and numerical viewpoint. Emphasizes techniques of proof and approximation, and their role in the solution of problems arising in applications. Prereq: Multivariable calculus and linear algebra.

MSSC 6040. Applied Linear Algebra. 3 cr. hrs.
Foundational linear algebra considered from a numerical viewpoint. Focuses on solutions of linear systems of equations, eigenvalues and eigenvectors, and transformations. Emphasizes and illustrates proof and numerical implementation using problems arising in applications. Prereq: Multivariable calculus and linear algebra.

MSSC 6090. Research Methods/Professional Development. 1 cr. hr.
Designed to introduce the process of research and communication of research in the mathematical and statistical sciences, including presentation and publication of research, preparation of grant proposals, and ethical considerations. May be repeated.

MSSC 6110. Applied Discrete Mathematics. 3 cr. hrs.
Applied discrete mathematics for the mathematics, engineering and computer science graduate student. Emphasis on graph theory and counting problems that serve as a foundation for research areas in the second term. Theory and applications are covered for topics including trees, graph coloring, chromatic polynomials, generating functions, recurrence relations, distinct colorings and Polya's Theorem. Prereq: COSC 1020 and MATH 1450 or equiv.; MATH 1451 and MATH 2100 or equiv.

MSSC 6120. Optimization. 3 cr. hrs.

MSSC 6130. Dynamical Systems. 3 cr. hrs.
Theory of discrete and continuous dynamical systems. Periodic solutions, bifurcations, chaotic systems, attractors, fractal dimension and simulation of these systems. Prereq: MATH 4200 or equiv.

MSSC 6210. Theory of Statistics. 3 cr. hrs.
Brief review of sampling distributions, convergence, Central Limit Theorem and Law of Large Numbers. Estimation, testing hypotheses, regression and correlation analysis, non-parametric methods. Prereq: MATH 4700 or equiv.

MSSC 6220. Analysis of Variance and Covariance. 3 cr. hrs.

MSSC 6230. Multivariate Statistical Analysis. 3 cr. hrs.
Basic properties of random vectors, multivariate normal distribution, estimations of mean vector and covariance matrix, Wishart distribution, hypothesis testing, Hotelling's T2, multivariate analysis of variance, principal component analysis, factor analysis, canonical correlation analysis, classification and discriminant analysis. A high level programming language may be used. Prereq: MATH 3100 or equiv; MATH 4710 or equiv.

MSSC 6240. Design and Analysis of Scientific Experiments. 3 cr. hrs.
Single factor, two-factor and multi-factor designs and their analysis, Latin-square design and its analysis; power analysis and sample size selection; 2^k factorial designs; confounding/blocking designs; orthogonality and orthogonal contrasts; 3^k factorial designs; response surface methodology. Prereq: A course in statistical methods, such as MATH 4720 or equiv.

MSSC 6250. Statistical Machine Learning. 3 cr. hrs.
Multivariate data and exploratory analysis, random vector and multivariate normal distribution, multivariate linear regression, principal component and other dimensional reduction techniques, linear discriminant analysis, recursive partition and tree-based methods including classification tree and regression tree, cluster analysis, neural network and support vector machine. Prereq: A course in statistical methods, such as MATH 4720, and a course in linear algebra, such as MATH 3100, MATH 4780 or equiv.; cons. of instr.

MSSC 6410. Real Analysis. 3 cr. hrs.
Involves study of algebraic structures of real analysis, function spaces, introduction to linear operators, measure and integration theory, convergence theorems, limits, continuity and derivatives. Prereq: MATH 4200.

MSSC 6420. Algebra. 3 cr. hrs.
Studies groups, rings, fields and vector spaces including Sylow's theorems, field of quotients of an integral domain, structure of finitely generated modules over a principal ideal domain, Galois theory of equations, ordered fields and classical groups. Prereq: MATH 4120 or equiv.

MSSC 6430. Logic and Set Theory. 3 cr. hrs.
Naive set theory, first-order logic, elementary model theory, non-standard analysis, Godel's incompleteness theorems for elementary arithmetic, axioms for set theory, ordinal and cardinal arithmetic, the continuum hypothesis, methods of inner models and forcing for proving consistency and independence results. Prereq: MATH 4120 or equiv.

MSSC 6440. Topology. 3 cr. hrs.
Metric spaces, fundamental topology notions, subspace topology, product spaces, quotient spaces, separation axioms, Tietze's theorem, compactness, metrization, uniform spaces, function spaces, homotopy relation, fundamental group, computing manifold groups. Prereq: MATH 4200 or equiv.
MSSC 6770. Innovations in Secondary Mathematics: Meeting the NCTM Standards. 3 cr. hrs.
Online course designed for teachers of secondary mathematics. Emphasizes relevant NCTM standards through discussion, projects, and implementation in a secondary mathematics classroom. Mathematics content amplifies and extends selected topics of secondary mathematics. Topics vary. Credit may be earned multiple times if completed under a different topic. Prereq: Cons. of dept. ch.; one term of calculus and access to an algebra or geometry class of secondary students; or cons. of course coordinator; admitted to MSST or College of Education.

MSSC 6931. Topics in Mathematical or Statistical Sciences. 3 cr. hrs.
Topics vary. Multiple enrollments allowed under different topics.

MSSC 6952. Colloquium in Mathematical or Statistical Sciences. 0 cr. hrs.
Research and scholarly presentations on selected topics in the mathematical or statistical sciences by visiting researchers, departmental faculty and graduate students. Prereq: Grad. stdng.

MSSC 6953. Seminar in Mathematics Curriculum Development and Material 1. 3 cr. hrs.
The historical evolution of mathematics learning theories and research-generated conceptions of mathematics learning; comparisons of various learning theories and their impact on research in mathematics learning; implications of research and learning theories on curriculum development; implications of mathematics learning research/theories on the teaching and learning of mathematics. Prereq: Admitted to MSST or College of Education.

MSSC 6954. Seminar in Mathematics Curriculum Development and Material 2. 3 cr. hrs.
Philosophy of education with particular attention to mathematics education; development by students of useful curricula in the form of teaching units, evaluation materials, and student and teacher bibliographies for specific topics, grade levels, and ability groups; aspects of supervision as related to the role of department chairperson. Prereq: MSSC 6953; admitted to MSST or College of Education.

MSSC 6960. Seminar in Mathematical or Statistical Sciences. 1-3 cr. hrs.
Topics selected from one of the various branches of mathematics or statistics. Specific topics are announced in the Schedule of Classes.

MSSC 6974. Practicum for Research in Mathematical or Statistical Sciences. 1-3 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

MSSC 6975. Practicum for Statistical Consulting. 3 cr. hrs.
Provides students with the opportunity to explore real-world examples of data analysis as a statistical consultant. Prereq: 3.000 MU GPA; completed at least 12 credit hours; cons. of the applied statistics dir. of graduate studies; or cons. of dept. ch.

MSSC 6998. Professional Project in Mathematical or Statistical Sciences. 0 cr. hrs.
SNC/UNC grade assessment. Prereq: Cons. of instr. and cons. of dept. ch.

MSSC 8995. Independent Study in Mathematical or Statistical Sciences. 1-3 cr. hrs.
In-depth research on a topic or subject matter usually not offered in the established curriculum with faculty and independent of the classroom setting. Prereq: Cons. of instr. and cons. of dept. ch.

MSSC 8999. Doctoral Dissertation. 1-12 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.
MSSC 9989. Doctoral Qualifying Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of full-time status. Requires that the student is working 20 hours or more per week toward their doctoral qualifying exam. May be taken in conjunction with credit-bearing or other non-credit courses to result in the status indicated, as deemed appropriate by the department. Prereq: Cons. of dept. ch.

MSSC 9991. Professional Project Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of less than half-time status. Requires that the student is working less than 12 hours per week on their professional project. Any professional project credits required for the degree should be completed before registering for non-credit Professional Project Continuation. Prereq: Cons. of dept. ch.

MSSC 9992. Professional Project Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of half-time status. Requires that the student is working more than 12 to less than 20 hours per week on their professional project. Any project credits required for the degree should be completed before registering for non-credit Professional Project Continuation. Prereq: Cons. of dept. ch.

MSSC 9993. Professional Project Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of full-time status. Requires that the student is working 20 hours or more per week on their professional project. Any professional project credits required for the degree should be completed before registering for non-credit Professional Project Continuation. Prereq: Cons. of dept. ch.

MSSC 9994. Master’s Thesis Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of less than half-time status. Requires that the student is working less than 12 hours per week on their master’s thesis. All six thesis credits required for the degree should be completed before registering for non-credit Master’s Thesis Continuation. Prereq: Cons. of dept. ch.

MSSC 9995. Master’s Thesis Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of half-time status. Requires that the student is working more than 12 to less than 20 hours per week on their master’s thesis. All six thesis credits required for the degree should be completed before registering for non-credit Master’s Thesis Continuation. Prereq: Cons. of dept. ch.

MSSC 9996. Master’s Thesis Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of full-time status. Requires that the student is working 20 hours or more per week on their master’s thesis. All six thesis credits required for the degree should be completed before registering for non-credit Master’s Thesis Continuation. Prereq: Cons. of dept. ch.

MSSC 9997. Doctoral Dissertation Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of less than half-time status. Requires that the student is working less than 12 hours per week on their doctoral dissertation. All 12 dissertation credits required for the degree should be completed before registering for non-credit Doctoral Dissertation Continuation. Prereq: Cons. of dept. ch.

MSSC 9998. Doctoral Dissertation Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Allows a student to be considered the equivalent of half-time status. Requires that the student is working more than 12 to less than 20 hours per week on their doctoral dissertation. All 12 dissertation credits required for the degree should be completed before registering for non-credit Doctoral Dissertation Continuation. Prereq: Cons. of dept. ch.

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