

DEPARTMENT OF MATHEMATICAL SCIENCES

College of Sciences and Humanities

Department of Mathematical Sciences
233 Mathematics and Computer Science Building
Kent Campus
330-672-2430
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www.kent.edu/math

Undergraduate Programs

Minors

Graduate Programs

Certificates

Graduate Certificates

- CCP Credentialing in Mathematics

Department of Mathematical Sciences Faculty

- Adams, Lynn (2007), Senior Lecturer, M.S., University of Akron, 2007
- Al-Niemi, Fearase (2024), University of Akron
- Alexopoulos, John K. (1994), Associate Professor, Ph.D., Kent State University, 1992
- Allen, Aaron C. (2014), Lecturer, B.S., Rensselaer Polytechnic Institute, 2011
- Allouba, Hassan A. (2002), Associate Professor, Ph.D., Cornell University, 1996
- Altobelli, Joseph A. (1997), Associate Professor, Ph.D., The Ohio State University, 1996
- Andaloro, Paul J. (1994), Assistant Professor, Ph.D., The Ohio State University, 1989
- Andriyevskyy, Volodymyr (2000), Professor, Ph.D., Institute of Mathematics of Ukrainian Academy of Sciences, 1986
- Arokiasamy, Daisy Malini (2015), Lecturer, M.S., Kent State University, 2016
- Barb, Cynthia M. (1990), Associate Professor, Ph.D., Kent State University, 1997
- Benjamin, Judy I. (2002), Assistant Professor, Ph.D., Kent State University, 2022
- Chebotar, Mikhail (2006), Professor, Ph.D., Moscow State University, 1999
- Clos, Timothy G. (2020), Assistant Professor, Ph.D., University of Toledo, 2017
- Das, Lovejoy S. (1989), Professor, Ph.D., University of Lucknow, 1979
- Davidson, Morley A. (1996), Associate Professor, Ph.D., University of Michigan, 1995
- de la Cruz Cabrera, Omar (2016), Associate Professor
- Dhaher, Yaser Y. (1989), Professor, Ph.D., Kent State University, 2007
- Dinh, Hai Q. (2004), Professor, Ph.D., Ohio University, 2003
- Dunlap, Laurie A. (2021), Associate Professor, Ph.D., University of Cincinnati, 2005
- Fesli, Emily E. (2021), Lecturer, M.S., Cleveland State University, 2021
- Gordon, Peter (2017), Associate Professor, Ph.D., Moscow University, 1999
- He, Min (1995), Professor, Ph.D., Southern Illinois University-Carbondale, 1994
- Hovhannisyan, Gro (2003), Professor, Ph.D., Yerevan State University, 1990
- Jahangiri, Jay M. (1994), Professor, Ph.D., University of York, 1986
- Jiafeng, Jin (2014), Lecturer, Ph.D., Kent State University, 2024
- Kasturiarachi, Aloysius B. (1995), Associate Professor, Ph.D., University of North Carolina-Charlotte, 1993
- Khan, Mohammad K. (1981), Professor, Ph.D., Case Western Reserve University, 1980
- Kover, Janice S. (1996), Associate Professor, Ph.D., Kent State University, 2001
- Kracht, Darci L. (1984), Professor, Ph.D., Kent State University, 2011
- Kratky, Joseph J. (2005), Associate Lecturer, M.S., Kent State University, 2011
- Law, Chelsea C. (2021), Associate Lecturer, M.S., Clemson University, 2012
- Lewis, Mark L. (1996), Professor, Ph.D., University of Wisconsin-Madison, 1995
- Li, Jing (2003), Associate Professor, Ph.D., New York University, 2002
- Li, Jun (2013), Associate Professor, Ph.D., Iowa State University, 2013
- Lochmueller, Kerri K. (2005), Associate Lecturer, M.S., Youngstown State University, 2008
- Meinke, Ashley M. (2009), Lecturer, M.S., Kent State University, 2011
- Miller, Robert L. (2021), Lecturer, M.S., Miami University, 2006
- Mocioalca, Oana (2004), Associate Professor, Ph.D., University of Florida, 2002
- Mulqueeny, Ellen S. (2005), Professor, M.S., Cleveland State University, 1993
- Najafi, Mahmoud (1995), Professor, Ph.D., Wichita State University, 1994
- Nazarov, Fedor L. (2011), Professor, M.S., Youngstown State University, 1990
- Neal, Todd A. (2010), Assistant Professor, Ph.D., University of Alabama, 2016
- Ngunkeng, Grace (2021), Associate Professor, Ph.D., Bowling Green State University, 2013
- Osikiewicz, Beth-Allyn (1994), Associate Professor, Ph.D., Kent State University, 2000
- Osikiewicz, Jeffrey A. (1990), Associate Professor, Ph.D., Kent State University, 1997
- Palfy-Muhoray, Peter (1987), Professor
- Palocyi, Frank J. (1991), Associate Lecturer, M.S., Youngstown State University, 1990
- Perera, Vicumpriya S. (1998), Associate Professor, Ph.D., Purdue University, 1993
- Pham, Tuyet D. (1988), Senior Lecturer, M.S., University of Akron, 1988
- Rajaram, Rajeev (2008), Professor, Ph.D., Iowa State University, 2005
- Reed, Beverly M. (1986), Professor, Ph.D., Kent State University, 2007
- Reichel, Lothar (1991), Professor, Ph.D., University of Stockholm, 1982

- Ritchey, Nathan P. (2016), Professor
- Ruff, Oliver (2009), Associate Professor, Ph.D., University of Oregon, 2002
- Ryabogin, Dmitry (2007), Professor, Ph.D., University of Jerusalem, 2001
- Sarver, Michael W. (2021), Associate Professor, Ph.D., Bowling Green State University, 2006
- Schmalzried, Robert J. (2017), Associate Lecturer, M.S.Ed., Youngstown State University, 2004
- Smithies, Laura A. (1997), Associate Professor, Ph.D., University of Utah, 1997
- Soprunova, Evgenia (2007), Professor, Ph.D., University of Toronto, 2002
- Spalsbury, Angela S. (2018), Associate Professor, Ph.D., Kent State University, 1996
- Stadden, Jared M. (2013), Associate Lecturer, M.B.A., Kent State University, 2012
- Taha, Nader F. (1990), Senior Lecturer, M.S., Tennessee State University, 1989
- Trehan, Dawn M. (2019), Assistant Professor, M.S., Case Western Reserve, 1996
- Tsai, Tsung-Heng (2019), Associate Professor, Ph.D., Virginia Tech, 2014
- Vezvaei, Mahbobeh (1983), Professor, Ph.D., Case Western Reserve University, 1987
- Vorhauer, Ulrike M. (2001), Associate Professor, Ph.D., University of Ulm, 1996
- Wakita, Hideki (1998), Senior Lecturer, M.A., Kent State University, 2002
- White, Donald L. (1989), Professor, Ph.D., Yale University, 1987
- Wright, Brian M. (1998), Associate Professor, Ph.D., Kent State University, 2007
- Yeon, Hyemin (2024), Assistant Professor, Ph.D., Iowa State University, 2023
- Yu, Gang (2006), Associate Professor, Ed.D., University of Georgia, 2000
- Zheng, Xiaoyu (2006), Professor, Ph.D., University of North Carolina-Chapel Hill, 2006
- Zvavitch, Artem (2004), Professor, Ph.D., Weizmann Institute of Science, 2002

Mathematics (MATH)

MATH 00020 PRE-ALGEBRA 2 Credit Hours

Course covers properties of whole numbers, fractions, decimals, percents, signed numbers and order of operations. Mental math and elementary algebraic thinking skills are emphasized. Use of calculators is not allowed. Course does not count toward graduation.

Prerequisite: 0-9 ALEKS math score.

Schedule Type: Emporium

Contact Hours: 2 other

Grade Mode: Standard Letter

MATH 00021 BASIC ALGEBRA I 2 Credit Hours

Course includes operations on integers, fractions, decimals and percents, and properties of real numbers. Introduction to variables, first degree equations and problem-solving with formulas. Equations and inequalities in one variable, linear equations, rate of change and slope, graphing in the cartesian plane. Course does not count toward graduation.

Prerequisite: Minimum 10 ALEKS math score.

Pre/corequisite: MATH 00020 with a minimum C grade.

Schedule Type: Emporium

Contact Hours: 2 other

Grade Mode: Standard Letter

MATH 00022 BASIC ALGEBRA II 2 Credit Hours

Introduction to functions, systems of linear equations, exponents, polynomial operations, scientific notation. Factoring polynomials, solving quadratics by factoring, radicals and rational exponents. Course does not count toward graduation.

Prerequisite: Minimum 25 ALEKS math score; or MATH 00021 with a minimum C grade.

Schedule Type: Emporium

Contact Hours: 2 other

Grade Mode: Standard Letter

MATH 00095 SPECIAL TOPICS IN MATHEMATICS 1-4 Credit Hours

(Repeatable for credit) Topics in mathematics not covered in regular courses. Offered when opportunities and resources permit; the topic is announced when the course is scheduled. Course does not count toward graduation.

Prerequisite: None.

Schedule Type: Emporium

Contact Hours: 1-4 other

Grade Mode: Standard Letter

MATH 10038 STATISTICAL THINKING 2 Credit Hours

This course is the first of a two-part sequence and provides a pathway for successful completion of MATH 10041 during the subsequent semester. Topics include graphical displays of data, measures of center and variation, linear regression and basic probability. In the context of these statistical concepts, students review basic arithmetic and algebra skills needed to succeed in MATH 10041, including computations and applications of percents and decimals, fractions, proportions, linear equations, areas of geometric figures, slope and intercepts. The development of study strategies, problem-solving skills and reading skills are interwoven throughout the semester. This course is different than basic algebra courses and MATH 10041 because it develops students' fluency within the context of statistical situations and does not cover all topics required in the TMM-011, nor does it cover them in depth. Emphasis is on skill development and foreshadowing statistical concepts through intuitive and informal development.

Prerequisite: None.

Schedule Type: Lecture

Contact Hours: 2 lecture

Grade Mode: Standard Letter

MATH 10040 INTRODUCTORY STATISTICS PLUS (KMCR) 5 Credit Hours

(Equivalent to MATH 10041) An introduction to statistical thinking and statistical methods with a review of basic algebra. Emphasis is on statistical literacy, conceptual understanding and active learning in the classroom. This course also provides just-in-time remediation to help students achieve the same learning outcomes as MATH 10041. No credit earned for this course if a student already earned credit for MATH 10041. Students who do not meet the prerequisites but do have a minimum of 3.0 high school GPA should contact the department for approval to register.

Prerequisite: ALEKS Math score between 25 and 34; or MATH 00021 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, TAG Mathematics, Transfer Module Mathematics

MATH 10041 INTRODUCTORY STATISTICS (KMCR) 4 Credit Hours

(Equivalent to MATH 10040) An introduction to statistical thinking and statistical methods. Emphasis is on statistical literacy, conceptual understanding and active learning in the classroom. No credit earned for this course if a student already earned credit for MATH 10040. Students who do not meet the prerequisites but do have a minimum of 3.5 high school GPA should contact the department for approval to register.

Prerequisite: Minimum 22 ACT math score; or minimum 530 SAT math score; or minimum 35 ALEKS math score; or MATH 00022 or MATH 10038 with minimum C grade; or MATH 10050 or any higher-level Mathematics (MATH) course.

Schedule Type: Emporium

Contact Hours: 4 other

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 10050 QUANTITATIVE REASONING PLUS (KMCR) 5 Credit Hours

(Equivalent to MATH 10051) In the broadest sense, mathematics should provide students the needed quantitative tools, logical reasoning and problem-solving skills, as well as a sense that quantitative modeling can be used to describe and understand developments in many areas of daily living. Since critical thinking is the course's primary objective and outcome - in each area of concentration (numeracy, mathematical modeling, probability and statistics) - students need to read and glean information from the problem situation, convert the information into a usable form, perform any needed routine calculations, make or draw a conclusion and communicate the result via explanation using quantitative reasoning by writing coherent statements and paragraphs. This course also provides just-in-time remediation to help students achieve the same learning outcomes as MATH 10051. Students who do not meet the prerequisites but do have a minimum of 3.0 high school GPA should contact the department for approval to register.

Prerequisite: None.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, TAG Mathematics, Transfer Module Mathematics

MATH 10051 QUANTITATIVE REASONING (KMCR) 4 Credit Hours

(Equivalent to MATH 10050) In the broadest sense, mathematics should provide students the needed quantitative tools, logical reasoning and problem solving skills, and a sense that quantitative modeling can be used to describe and understand developments in many areas of daily living. Since critical thinking is the primary objective and outcome for this course, in each area of concentration (numeracy, mathematical modeling and probability and statistics), students will read and glean information from the problem situation, convert the information into a usable form, perform any needed routine calculations, make or draw a conclusion, and then communicate the result via explanation using quantitative reasoning by writing coherent statements and paragraphs. Students who do not meet the prerequisites but do have a minimum of 3.5 high school GPA should contact the department for approval to register.

Prerequisite: Minimum 22 ACT math score; or minimum 530 SAT math score; or minimum 35 ALEKS Math score; or MATH 00022 with a minimum C grade; or any higher level MATH course.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 10475 ALGEBRAIC THINKING 2 Credit Hours

This course includes development of problem-solving skills, including recognizing quantities in real-world scenarios, noting dependency relationships of these quantities, creating accurate diagrams of the varying quantities in scenarios, precisely describing variables and quantities, identifying domains in context and representing the varying relationship of two quantities on a coordinate plane. Algebra skills reviewed include factoring, solving linear and non-linear equations and simplifying rational expressions and expressions with integer and rational exponents. The modeling component includes recognizing linear vs. exponential change and writing function models for linear and exponential growth and decay.

Prerequisite: MATH 00022 with a minimum C grade; or minimum 22 ACT math score; or minimum 530 SAT math score; or ALEKS math score between 35-44.

Schedule Type: Lecture

Contact Hours: 2 lecture

Grade Mode: Standard Letter

MATH 10675 ALGEBRA FOR CALCULUS BOOST (KMCR) 5 Credit Hours

(Equivalent to MATH 10775 and MATH 11010) Course includes an extensive and rich immersion into the structure of functions. Routine analysis includes discussion of domain, range, zeros, general function behavior (increasing, decreasing, extrema, etc.). Operations with functions, including addition, subtraction, multiplication, division, composition and inversion. Functions are studied as a tool to analyze rates of change for real-world scenarios. The emphasis is on linear, polynomial, exponential and rational functions, with an extensive problem-solving component. A two-week review of intermediate algebra skills is included in the course, as is extra time studying quadratic functions, absolute value functions, systems of equations and extended time on logarithms. Students who do not meet the prerequisites but have a minimum 3.5 high school GPA should contact the department for approval to register.

Prerequisite: MATH 00022 with a minimum C grade; or minimum 22 ACT math score; or minimum 530 SAT math score; or ALEKS math score between 35 and 44.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 10771 BASIC MATHEMATICAL CONCEPTS I PLUS (KMCR) 5 Credit Hours

(Equivalent to MATH 14001) Course covers the development of the real-number system and its sub-systems, open sentences, numeration systems, modular arithmetic and some number theory concepts. Additional concepts covered include place value, logic, equality, properties of the real numbers, multiple representations of operations with numbers, and problem solving. Students who do not meet the prerequisites but do have a minimum of 3.5 high school GPA should contact the department for approval to register.

Prerequisite: Minimum 35 ALEKS math score; or minimum 22 ACT math score; or minimum 530 SAT math score; or MATH 00022 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning

MATH 10772 MODELING ALGEBRA PLUS (KMCR) 5 Credit Hours

(Equivalent to MATH 11009) Study of algebra arising in the context of real-world applications, including linear, polynomial, exponential and logarithmic models. Includes a review of factoring and functions. Course is intended for students not planning to take calculus. No credit earned toward a degree for this course if student already earned credit for MATH 11010. Students who do not meet the prerequisites but do have a minimum of 3.5 high school GPA should contact the department for approval to register.

Prerequisite: Minimum 35 ALEKS math score; or minimum 22 ACT math score; or minimum 530 SAT math score; or MATH 00022 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning

MATH 10775 ALGEBRA FOR CALCULUS PLUS (KMCR) 4 Credit Hours

(Equivalent to MATH 10675 and MATH 11010) Course includes an extensive and rich immersion into the structure of functions. Routine analysis includes discussion of domain, range, zeros, general function behavior (increasing, decreasing, extrema, etc.). Operations with functions, including addition, subtraction, multiplication, division, composition and inversion. Functions are studied as a tool to analyze rates of change for real-world scenarios. The emphasis is on linear, polynomial, exponential and rational functions, with an extensive problem-solving component. Skill review is included throughout the course, as is time studying quadratic functions, absolute value functions, systems of equations and extended time with logarithms.

Prerequisite: MATH 10475 or MATH 10772 with a minimum C grade; or ALEKS math score between 45 and 54.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 11008 EXPLORATIONS IN MODERN MATHEMATICS (KMCR) 3 Credit Hours

Topics from various branches of mathematics will be chosen to introduce the student to the wide varieties of ways in which mathematics affects everyday life. Students who do not meet the prerequisites but do have a minimum of 3.5 high school GPA should contact the department for approval to register.

Prerequisite: Minimum 35 ALEKS math score; or minimum 22 ACT math score; or MATH 00022 or any higher MATH course with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning

MATH 11009 MODELING ALGEBRA (KMCR) 4 Credit Hours

(Equivalent to MATH 10772) Study of algebra arising in the context of real-world applications, including linear, polynomial, exponential and logarithmic models. Intended for students not planning to take calculus. No credit earned toward a degree for this course if the student already earned credit for MATH 11010.

Prerequisite: Minimum 45 ALEKS math score.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning

MATH 11010 ALGEBRA FOR CALCULUS (KMCR) 3 Credit Hours
(Equivalent to MATH 10675 and MATH 10775) Course includes an extensive and rich immersion into the structure of functions. Routine analysis includes discussion of domain, range, zeros, general function behavior (increasing, decreasing, extrema, etc.). Operations with functions, including addition, subtraction, multiplication, division, composition and inversion. Functions are studied as a tool to analyze rates of change for real-world scenarios. The emphasis is on linear, polynomial, exponential and rational functions, with an extensive problem-solving component.

Prerequisite: MATH 10772 or MATH 11009 with a minimum B grade; or minimum 55 ALEKS math score.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 11012 INTUITIVE CALCULUS (KMCR) 3 Credit Hours
Course is designed to give an overview of differential and integral calculus to business and life-science majors. Course does not include trigonometric functions. No credit earned toward a degree for this course if the student already earned credit for MATH 12002.

Prerequisite: Minimum 67 ALEKS math score; or minimum C grade in MATH 10675 or MATH 10775 or MATH 11010.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 11022 TRIGONOMETRY (KMCR) 3 Credit Hours
Solution of triangles, trigonometric equations and identities.
Prerequisite: Minimum 67 ALEKS math score; or minimum C grade in MATH 10675 or MATH 10775 or MATH 11010.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 12002 ANALYTIC GEOMETRY AND CALCULUS I (KMCR) 5 Credit Hours
Concepts of limit, continuity and derivative, and the indefinite and definite integral for functions of one real variable. Maximization, related rates, fundamental theorem of calculus. No credit earned toward a degree for this course if the student already earned credit for MATH 12011 and MATH 12012.

Prerequisite: Minimum 78 ALEKS math score; or MATH 11022 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 12003 ANALYTIC GEOMETRY AND CALCULUS II 5 Credit Hours
Continued study of techniques and applications of integration; trigonometric, logarithmic and exponential functions; polar coordinates; vectors; parametric equations; sequences and series.

Prerequisite: MATH 12002 or MATH 12012 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 5 lecture

Grade Mode: Standard Letter

Attributes: Transfer Module Mathematics

MATH 12011 CALCULUS WITH PRECALCULUS I (KMCR) 3 Credit Hours
Introduction to differential calculus with a review of algebra and trigonometry. Includes exponents, factoring, functions, graphs, tangent lines, limits, continuity, derivatives and related rates. No credit earned toward a degree for this course if the student already earned credit for MATH 12002.

Prerequisite: Minimum 67 ALEKS math score.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 12012 CALCULUS WITH PRECALCULUS II (KMCR) 3 Credit Hours
Development of integral calculus and continued study of differential calculus. Includes curve sketching optimization fundamental theorem of calculus areas between curves, exponential and logarithmic functions. No credit earned toward a degree for this course if student already earned credit for MATH 12002.

Prerequisite: MATH 12011 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 12013 BRIEF CALCULUS II 3 Credit Hours
This is a condensed version of MATH 12003 to meet the needs of majors that do not require the full force of MATH 12003. The course starts with integration by parts, approximating integrals, and applications of integrals. It follows with a brief introduction to series, parametric equations and polar coordinates, and finishes with vectors and geometry of space. No credit earned toward a degree for this course if student already earned credit for MATH 12003.

Prerequisite: Minimum C grade in MATH 12002 or MATH 12012 or MATH 12021.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 12021 CALCULUS FOR LIFE SCIENCES 4 Credit Hours
Differential and integral calculus using examples and problems in life sciences.

Prerequisite: Minimum 78 ALEKS math score; or MATH 11022 or MATH 12011 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 12022 PROBABILITY AND STATISTICS FOR LIFE SCIENCES 3 Credit Hours

Probability and statistics with applications in medical and biological sciences.

Prerequisite: Minimum C grade in MATH 12002 or MATH 12012 or MATH 12021.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 14001 BASIC MATHEMATICAL CONCEPTS I (KMCR) 4 Credit Hours

(Equivalent to MATH 10771) Development of the real number system and its sub-systems, open sentences, numeration systems, modular arithmetic and some number theory concepts.

Prerequisite: MATH 10675 or any higher level MATH course (except MATH 11008) with a minimum C grade; or minimum 45 ALEKS math score.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 14002 BASIC MATHEMATICAL CONCEPTS II (KMCR) 4 Credit Hours

Basic concepts of probability, statistics and geometry.

Prerequisite: MATH 10771 or MATH 14001 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: Kent Core Mathematics and Critical Reasoning, Transfer Module Mathematics

MATH 19099 FIELD EXPERIENCE IN MATHEMATICS INSTRUCTION (ELR) 1 Credit Hour

(Repeatable for credit) Learning through tutoring. A supervised lab experience in providing explanations of mathematical concepts.

Prerequisite: Special approval.

Schedule Type: Lecture

Contact Hours: 1 lecture

Grade Mode: Standard Letter

Attributes: Experiential Learning Requirement

MATH 20011 DECISION-MAKING UNDER UNCERTAINTY 3 Credit Hours

An introductory course on applied statistics. The course provides a hands-on approach to understanding, quantification and decision-making under various forms of uncertainty. The main topics include visualization of uncertainty, probabilistic quantification of uncertainty, Bayesian and non-Bayesian ways of decision-making under uncertainty. Class activities incorporate active learning elements, including in-classroom computation with professional-grade software for statistical analysis and simulation.

Prerequisite: MATH 12002 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 20095 SPECIAL TOPICS IN MATHEMATICS 1-5 Credit Hours
(Repeatable for credit) Various special courses will be announced in the schedule of classes under this course number with different section numbers.

Prerequisite: Special approval.

Schedule Type: Lecture

Contact Hours: 1-5 lecture

Grade Mode: Standard Letter

MATH 21001 LINEAR ALGEBRA 3 Credit Hours

Systems of linear equations and the associated matrix operations, linear transformations, vector spaces, bases, eigenvectors.

Prerequisite: Minimum C grade in MATH 11012 or MATH 12002 or MATH 12012 or MATH 12021.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: TAG Mathematics

MATH 21002 APPLIED LINEAR ALGEBRA 3 Credit Hours

This is an introductory course in linear algebra. The goal of the course is to teach the math fundamentals of linear algebra in a way that focuses more on applications. The topics include systems of linear equations, matrix operations, vector spaces, eigenvalues and eigenvectors, singular value decompositions, and their applications.

Prerequisite: Minimum C grades in MATH 12002 or MATH 11012 or MATH 12012 or MATH 12021.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 21092 COMPUTER PRACTICUM (ELR) 2 Credit Hours

(Repeatable for credit) Supervised work experience in a computer installation.

Prerequisite: None.

Schedule Type: Practical Experience

Contact Hours: 2 other

Grade Mode: Standard Letter

Attributes: Experiential Learning Requirement

MATH 22005 ANALYTIC GEOMETRY AND CALCULUS III 4 Credit Hours

Study of functions of several variables, including partial derivatives and multiple integrals.

Prerequisite: MATH 12003 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: TAG Mathematics

MATH 23022 DISCRETE STRUCTURES FOR COMPUTER SCIENCE 3 Credit Hours

(Cross-listed with CS 23022) Discrete structures for computer scientists with a focus on: mathematical reasoning, combinatorial analysis, discrete structures, algorithmic thinking, applications and modeling. Specific topics include propositional and predicate logic and logical modeling using Boolean algebra and logical gates, information representation using binary system, sets, functions, relations, logical argumentation, proof techniques, recursion and recursive modeling, sequences and summation, arithmetic and geometric progressions, algorithms, iterative vs recursive algorithms, mathematical and structural induction, recursive structures, counting, permutation and combination, binomial expansion, matrices and matrix-operations, graphs and trees and their traversal, probability and Bayes' theorem, finite state machines, their modeling and applications, Regular grammar, basics of number theory, modeling computation and Turing machines, decidability and halting problem.

Prerequisite: Minimum C grade in MATH 11009 or MATH 11010 or MATH 11022, or ALEKS score of 78.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 30011 BASIC PROBABILITY AND STATISTICS 3 Credit Hours

Analysis and representation of data. Controlled experiments and observations. Measurement errors. Correlation and regression. Sampling. Probability models and tests of models. Inference. This course cannot be used to meet the mathematics requirements for a BA in Mathematics or a BS in Applied Mathematics or Mathematics.

Prerequisite: Minimum 67 ALEKS math score; or minimum C grade in MATH 10675 or MATH 10775 or MATH 11010; or any course MATH 11012 to MATH 12022; or any course MATH 20000 to MATH 49999.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 30055 MATHEMATICAL THEORY OF INTEREST 3 Credit Hours

A calculus-based introduction to the mathematics of finance. Limited to deterministic analysis of interest rates annuities bonds and immunization. Emphasizes the mathematical theory of the subject matter.

Prerequisite: MATH 12003 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 31011 PROOFS IN DISCRETE MATHEMATICS 3 Credit Hours

The study of discrete mathematical structures including sets, functions and relations. The course includes an introduction to logical thinking with an emphasis on proof techniques. The course may include topics in number theory, graph theory and combinatoric.

Prerequisite: MATH 12002 with a minimum C grade.

Pre/corequisite: Minimum C grade in the following courses: MATH 21001 or MATH 21002 or MATH 32051.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 32044 ORDINARY DIFFERENTIAL EQUATIONS 3 Credit Hours

An introduction to ordinary differential equations and applications.

Topics include solution methods, series solutions, singular points, Laplace transforms and linear systems. Applications include population dynamics, forced oscillations and resonance.

Prerequisite: Minimum C grade in the following courses: MATH 12003 or MATH 12013; and MATH 21001 or MATH 21002.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: TAG Mathematics

MATH 32051 MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES I 4 Credit Hours

Mathematics background beyond calculus I and II for upper-division courses in the physical sciences. Topics include complex numbers and arithmetic, linear algebra, partial differentiation and multiple integrals.

Prerequisite: MATH 12003 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 32052 MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES II 4 Credit Hours

Additional mathematics background for upper-division courses in the physical sciences. Topics include vector analysis, Fourier series and transforms ordinary differential equations and partial differential equations.

Prerequisite: MATH 32051 with a minimum C grade; or MATH 21001 and MATH 22005 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 34001 FUNDAMENTAL CONCEPTS OF ALGEBRA 3 Credit Hours

Professionalized course in algebra for prospective secondary teachers. Postulational development of number system of algebra; other systems, related topics, applications. This course cannot be used to meet the mathematical requirements for a BA in Mathematics or a BS in either Applied Mathematics or Mathematics. No credit earned toward a degree for this course if a student already earned credit for MATH 41001.

Prerequisite: MATH 12002 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 34002 FUNDAMENTAL CONCEPTS OF GEOMETRY 3 Credit Hours

Professionalized course in geometry for secondary school teachers. Origin and development of the geometry of Euclid with modern refinements, topics, approaches. Other geometries, applications. This cannot be used to meet the mathematics requirement for a BA in Mathematics or a BS in either Applied Mathematics or Mathematics.

Prerequisite: MATH 12002 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 38001 HANDS-ON MATHEMATICS 3 Credit Hours

Students take turns learning a topic and then teach that topic to the class. No text is required; the students use web resources and materials supplied by the instructor. Many of the topics have a hands-on component. Some examples are two- and three-dimensional tiling problems, the Towers of Hanoi and other problems with an inductive solution, and 'magic tricks' with a basis in algebra, parity or modular arithmetic.

Prerequisite: MATH 12003 with a minimum C grade.

Schedule Type: Seminar

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 40011 PROBABILITY THEORY AND APPLICATIONS 3 Credit Hours

(Slashed with MATH 50011) Permutations and combinations, discrete and continuous distributions, random variables, conditional probabilities, Baye's formula, mathematical expectation, law of large numbers, normal approximations, basic limit theorems.

Prerequisite: MATH 22005 or MATH 32051 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 40012 THEORY OF STATISTICS (WIC) 3 Credit Hours

(Slashed with MATH 50012) Sample spaces, continuous distributions, sampling distributions, point and interval estimation, hypothesis testing, types of error, level and power of tests, sequential and nonparametric methods.

Prerequisite: MATH 40011 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

Attributes: Writing Intensive Course

MATH 40015 APPLIED STATISTICS 3 Credit Hours

(Slashed with MATH 50015) Course is based on classical linear regression techniques with an emphasis on real data using the principles of sound data analysis. Close attention is given to issues of interpretation, diagnostics, outliers and influential points, goodness of fit and model selection. Topics include simple and multiple linear regression, transformation and modifications of covariates and responses, design matrices, variable selection and logistic regression. Students with statistics courses from other disciplines should consult with the Department of Mathematical Sciences for possible prerequisite overrides.

Prerequisite: MATH 21001 or MATH 21002 with a minimum C grade; and MATH 12022 with a minimum B grade or MATH 20011 with a minimum C grade or MATH 30011 with a minimum B grade or MATH 40012 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 40024 COMPUTATIONAL STATISTICS 3 Credit Hours

(Slashed with MATH 50024) This course is about the use of computational tools to manage, explore, summarize and visualize data, as well as the computational underpinnings of fitting statistical models. It uses mostly the statistical computation language R, but also other languages like Python and Matlab. It also covers: simulation and random number generation, computationally intensive methods like the bootstrap and permutation tests, Expectation-Maximization and related algorithms and dimensionality reduction via matrix decomposition. Students with statistics courses from other disciplines should consult with the Department of Mathematical Sciences for possible prerequisite overrides.

Prerequisite: MATH 21001 or MATH 21002 with a minimum C grade; and MATH 12022 with a minimum B grade or MATH 20011 with a minimum C grade or MATH 30011 with a minimum B grade or MATH 40012 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 40028 STATISTICAL LEARNING 3 Credit Hours

(Slashed with MATH 50028) This course is about the statistical foundations of modern machine learning techniques. The main focus is classification and prediction using regression-based, tree-based and kernel-based methods. Specific methods include logistic regression, classification and regression trees, random forests and support vector machines. The course also includes an introduction to unsupervised and semi-supervised learning.

Prerequisite: MATH 40015 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 40051 TOPICS IN PROBABILITY THEORY AND STOCHASTIC PROCESSES 3 Credit Hours

(Slashed with MATH 50051) Topics from conditional expectations, Markov chains, Markov processes, Brownian motion and Martingales and their applications to stochastic calculus.

Prerequisite: MATH 40011 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 40055 ACTUARIAL MATHEMATICS I (ELR) (WIC) 4 Credit Hours

(Slashed with MATH 50055) Topics from survival models, stochastic analysis of annuities and life insurance and casualty models. .

Prerequisite: MATH 30055 and MATH 40011 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

Attributes: Experiential Learning Requirement, Writing Intensive Course

MATH 40056 ACTUARIAL MATHEMATICS II 4 Credit Hours

(Slashed with MATH 50056) Benefit premiums, benefit reserves and their analysis, decrement models, joint survivorship, risk models.

Prerequisite: MATH 40055 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 40059 STOCHASTIC ACTUARIAL MODELS 3 Credit Hours
 (Slashed with MATH 50059) Topics from investment risk, mean variance analysis, CAPM, financial derivatives, binomial pricing model, stochastic calculus, Black-Scholes pricing model and Greeks.
Prerequisite: MATH 40011 with a minimum C grade.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

MATH 40093 VARIABLE TITLE WORKSHOP IN MATHEMATICS 1-6 Credit Hours
 (Repeatable for credit) Studies special topics in mathematics. Not acceptable for credit toward a major or minor in math without approval of student's adviser.
Prerequisite: Special approval.
Schedule Type: Workshop
Contact Hours: 1-6 other
Grade Mode: Satisfactory/Unsatisfactory

MATH 41001 MODERN ALGEBRA I (ELR) (WIC) 3 Credit Hours
 (Slashed with MATH 51001) Basic properties of groups, subgroups, factor groups. Basic properties of rings, integral domains and homomorphisms.
Prerequisite: MATH 22005 or MATH 32051 with a minimum C grade; and MATH 31011 with a minimum C grade.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter
Attributes: Experiential Learning Requirement, Writing Intensive Course

MATH 41002 MODERN ALGEBRA II (ELR) (WIC) 3 Credit Hours
 (Slashed with MATH 51002) A continuation of MATH 41001, emphasizing properties of rings, their ideals, polynomial ring extensions, fields, finite degree extensions, roots of polynomials, constructability.
Prerequisite: Minimum C grade in MATH 41001.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter
Attributes: Experiential Learning Requirement, Writing Intensive Course

MATH 41021 THEORY OF MATRICES 3 Credit Hours
 (Slashed with MATH 51021) A rigorous study of the topics introduced in matrix algebra. Topics included are vector space preliminaries, canonical forms of matrices, diagonalizability criteria.
Prerequisite: MATH 21001 and MATH 22005 with a minimum C grade.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

MATH 41038 INTERMEDIATE LOGIC 3 Credit Hours
 (Cross-listed with CS 41038 and PHIL 41038)(Slashed with MATH 51038 and PHIL 51038) A detailed, systematic study of symbolic logic for philosophy majors, mathematics majors, computer science majors and anyone else interested in advanced study in logic. The aim of the course is twofold: (1) to develop a facility in understanding and using symbolic logic for various purposes, and (2) to understand and appreciate symbolic logic as an area of study in itself. Topics include the distinction between syntactic, object-level proofs and semantic, meta-level proofs; the distinction between axiomatic systems and natural deduction systems of object-level proofs; various systems of modal logic; and some non-classical logics.
Prerequisite: Actuarial Mathematics major or Applied Mathematics major or Applied Mathematics minor or Applied Statistics minor or Mathematics major or Mathematics minor; and junior standing.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

MATH 42001 ANALYSIS I (ELR) (WIC) 3 Credit Hours
 (Slashed with MATH 52001) Topics include basic structure of the real numbers, Cauchy sequences, convergence, completeness of the real numbers, continuity, differentiation and Riemann integration.
Prerequisite: MATH 22005 or MATH 32051 with a minimum C grade; and MATH 31011 with a minimum C grade.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter
Attributes: Experiential Learning Requirement, Writing Intensive Course

MATH 42002 ANALYSIS II (ELR) (WIC) 3 Credit Hours
 (Slashed with MATH 52002) Topics include further development of integration theory, infinite series, uniform convergence, several variable calculus and metric spaces.
Prerequisite: MATH 42001 with a minimum C grade.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter
Attributes: Experiential Learning Requirement, Writing Intensive Course

MATH 42011 MATHEMATICAL OPTIMIZATION 3 Credit Hours
 (Slashed with MATH 52011) Analytic and numerical techniques for location of extreme points of functions and calculus of variations. Both constrained and unconstrained problems are considered.
Prerequisite: Minimum C grade in MATH 21001 and MATH 22005 or MATH 32051.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

MATH 42021 GRAPH THEORY AND COMBINATORICS 3 Credit Hours
 (Slashed with MATH 52021) Fundamentals and applications of combinatorial mathematics. Topics include traversability, colorability, networks, inclusion and exclusion, matching and designs.
Prerequisite: Minimum C grade in MATH 12003 or MATH 12013; and MATH 21001 or MATH 21002.
Schedule Type: Lecture
Contact Hours: 3 lecture
Grade Mode: Standard Letter

MATH 42024 NUMBERS AND GAMES 3 Credit Hours

(Slashed with MATH 52024) The study of partisan and impartial combinatorial games, games as numbers and Grundy-Sprague theory.

Prerequisite: Minimum C grade in MATH 21001 or MATH 21002.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 42031 MATHEMATICAL MODELS AND DYNAMICAL SYSTEMS 3 Credit Hours

(Slashed with MATH 52031) Formulation and analysis of mathematical models for a variety of phenomena. Mathematical methods from optimization, dynamical systems and probability are developed and applied. Modern software tools are utilized.

Prerequisite: Minimum C grade in the following courses: MATH 22005 and MATH 32044; or MATH 32052.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 42039 MODELING PROJECTS (ELR) (WIC) 3 Credit Hours

(Slashed with MATH 52039) Individual and small-group projects concerned with the formulation and analysis of mathematical models in a variety of areas. Written and oral reports are required.

Prerequisite: MATH 42031 with a minimum C grade.

Schedule Type: Seminar

Contact Hours: 3 other

Grade Mode: Standard Letter-IP

Attributes: Experiential Learning Requirement, Writing Intensive Course

MATH 42041 ADVANCED CALCULUS 3 Credit Hours

(Slashed with MATH 52041) The calculus and applications of scalar and vector functions of several variables. Vector differential and integral calculus. Applications to field theories, electricity and magnetism and fluid flow.

Prerequisite: MATH 21001 with a minimum C grade; and MATH 22005 or MATH 32051.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 42045 PARTIAL DIFFERENTIAL EQUATIONS 3 Credit Hours

(Slashed with MATH 52045) An introduction to Fourier series, Fourier transforms and partial differential equations. Wave, heat and potential equations of mathematical physics. Additional topics include Green's functions and the method of characteristics for wave equations.

Prerequisite: Minimum C grade in the following courses: MATH 22005 and MATH 32044; or MATH 32052.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 42048 COMPLEX VARIABLES 3 Credit Hours

(Slashed with MATH 52048) Algebra of complex numbers, analytic functions, mappings, Cauchy integral theory, residue theory and applications.

Prerequisite: MATH 22005 or MATH 32051 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 42201 NUMERICAL LINEAR ALGEBRA 3 Credit Hours

(Cross-listed with CS 42201)(Slashed with CS 52201 and MATH 52201) Fundamentals of numerical linear algebra; solving linear systems; QR factorization and least squares; iterative methods for eigenvalue problems.

Prerequisite: Minimum C grade in the following courses: CS 10062 or CS 13001 or (CS 13011 and CS 13012) or (ENGR 15300 and ENGR 15301) or ENGR 15302; and MATH 12003 or MATH 12013; and MATH 21001 or MATH 21002 or MATH 32051.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 42202 NUMERICAL APPROXIMATION AND OPTIMIZATION 3 Credit Hours

(Cross-listed with CS 42202)(Slashed with CS 52202 and MATH 52202) This course introduces numerical methods for solving nonlinear equations, optimizing functions, performing interpolation, computing differentiation and integration and solving differential equations.

Prerequisite: Minimum C grade in the following courses: CS 10062 or CS 13001 or (CS 13011 and CS 13012) or (ENGR 15300 and ENGR 15301) or ENGR 15302; and (MATH 22005 and MATH 32044) or MATH 32052.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 45011 DIFFERENTIAL GEOMETRY 3 Credit Hours

(Slashed with MATH 55011) Analytic and metric differential geometry of curves and surfaces.

Prerequisite: MATH 22005 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 45021 EUCLIDEAN GEOMETRY 3 Credit Hours

(Slashed with MATH 55021) Geometry of Euclid extended to advanced topics of the triangle, quadrilaterals and circles: cross-ratio, groups, constructions, geometric generalizations and inversion.

Prerequisite: Minimum C grade in MATH 21001 or MATH 21002.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 45022 LINEAR GEOMETRY 3 Credit Hours

(Slashed with MATH 55022) Use of transformations as a tool to study geometry and to differentiate between different kinds of geometry. Linear algebra methods applied to geometry.

Prerequisite: Minimum C grade in MATH 21001 or MATH 21002.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 46001 ELEMENTARY TOPOLOGY 3 Credit Hours

(Slashed with MATH 56001) Metric spaces, introduction to topological spaces, separation axioms.

Prerequisite: MATH 22005 with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 47011 THEORY OF NUMBERS 3 Credit Hours

(Slashed with MATH 57011) Divisibility properties of the integers, prime numbers, congruences, quadratic reciprocity, Diophantine equations, number theoretic functions, simple continued fractions and rational approximations.

Prerequisite: Minimum C grade in MATH 12003 or MATH 12013.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 47021 HISTORY OF MATHEMATICS 3 Credit Hours

(Slashed with MATH 57021) Survey from Babylonian and Egyptian mathematics to 20th century mathematics with emphasis on the development of algebra, geometry, calculus, number theory.

Prerequisite: MATH 23022 or higher with a minimum C grade.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 49992 INTERNSHIP IN MATHEMATICS (ELR) 1-3 Credit Hours

Supervised work experience and training in the mathematical sciences. Since this work will be outside the department a report and final presentation will be required.

Prerequisite: Special Approval.

Schedule Type: Practical Experience

Contact Hours: 0 lecture, 0 lab, 3-9 other

Grade Mode: Satisfactory/Unsatisfactory-IP

Attributes: Experiential Learning Requirement

MATH 49995 SELECTED TOPICS IN MATHEMATICS AND ITS APPLICATIONS 1-4 Credit Hours

(Repeatable for credit) Various special courses will be announced in the schedule of classes under this course number with different section numbers.

Prerequisite: Special approval.

Schedule Type: Lecture

Contact Hours: 1-4 lecture

Grade Mode: Standard Letter

MATH 49996 INDIVIDUAL STUDY 1-4 Credit Hours

(Repeatable for credit) Individual investigation in mathematics.

Prerequisite: Special approval.

Schedule Type: Individual Investigation

Contact Hours: 1-4 other

Grade Mode: Standard Letter

MATH 49998 RESEARCH (ELR) 1-15 Credit Hours

(Repeatable for credit) Research in mathematics.

Prerequisite: Special approval.

Schedule Type: Research

Contact Hours: 1-15 other

Grade Mode: Satisfactory/Unsatisfactory-IP

Attributes: Experiential Learning Requirement

MATH 50011 PROBABILITY THEORY AND APPLICATIONS 3 Credit Hours

(Slashed with MATH 40011) Permutations and combinations, discrete and continuous distributions, random variables, conditional probabilities, Baye's formula, mathematical expectation, law of large numbers, normal approximations, basic limit theorems.

Prerequisite: Graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 50012 THEORY OF STATISTICS 3 Credit Hours

(Slashed with MATH 40012) Sample spaces, continuous distributions, sampling distributions, point and interval estimation, hypothesis testing, types of error, level and power of tests, sequential and nonparametric methods.

Prerequisite: MATH 40011 or MATH 50011; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 50015 APPLIED STATISTICS 3 Credit Hours

(Slashed with MATH 40015) Course is based on classical linear regression techniques with an emphasis on real data using the principles of sound data analysis. Close attention is given to issues of interpretation, diagnostics, outliers and influential points, goodness of fit and model selection. Topics include simple and multiple linear regression, transformation and modifications of covariates and responses, design matrices, variable selection and logistic regression.

Prerequisite: Applied Mathematics major or Data Science major or Pure Mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 50024 COMPUTATIONAL STATISTICS 3 Credit Hours

(Slashed with MATH 40024) This course is about the use of computational tools to manage, explore, summarize and visualize data, as well as the computational underpinnings of fitting statistical models. It uses mostly the statistical computation language R, but also other languages like Python and Matlab. It also covers: simulation and random number generation, computationally intensive methods like the bootstrap and permutation tests, Expectation-Maximization and related algorithms and dimensionality reduction via matrix decomposition.

Prerequisite: Applied Mathematics major or Data Science major or Pure Mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 50028 STATISTICAL LEARNING 3 Credit Hours

(Slashed with MATH 40028) This course is about the statistical foundations of modern machine learning techniques. The main focus is classification and prediction using regression-based, tree-based and kernel-based methods. Specific methods include logistic regression, classification and regression trees, random forests and support vector machines. The course also includes an introduction to unsupervised and semi-supervised learning.

Prerequisite: MATH 40015 or MATH 50015; and MATH 40024 or MATH 50024; and Applied Mathematics major or Data Science major or Pure Mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 50051 TOPICS IN PROBABILITY THEORY AND STOCHASTIC PROCESSES 3 Credit Hours

(Slashed with MATH 40051) Topics from conditional expectations, Markov chains, Markov processes, Brownian Motion and Martingales and their applications to stochastic calculus.

Prerequisite: MATH 50011; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 50055 ACTUARIAL MATHEMATICS I 4 Credit Hours

(Slashed with MATH 40055) Topics from survival models, stochastic analysis of annuities and life insurance and casualty models.

Prerequisite: MATH 30055 and MATH 50011; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 50056 ACTUARIAL MATHEMATICS II 4 Credit Hours

(Slashed with MATH 40056) Benefit premiums, benefit reserves and their analysis; decrement models, joint survivorship, risk models.

Prerequisite: MATH 50055; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 50059 STOCHASTIC ACTUARIAL MODELS 3 Credit Hours

(Slashed with MATH 40059) Topics from investment risk, mean variance analysis, CAPM, financial derivatives, binomial pricing model, stochastic calculus, Black-Scholes pricing model and Greeks.

Prerequisite: MATH 40011 or MATH 50011; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 51001 MODERN ALGEBRA I 3 Credit Hours

(Slashed with MATH 41001) Basic properties of groups, subgroups, factor groups. Basic properties of rings, integral domains and homomorphisms.

Prerequisite: MATH 21001 and MATH 22005; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 51002 MODERN ALGEBRA II 3 Credit Hours

(Slashed with MATH 41002) A continuation of MATH 51001, emphasizing properties of rings, their ideals, polynomial ring extensions, fields, finite degree extensions, roots of polynomials, constructibility.

Prerequisite: MATH 41001 or MATH 51001; and applied mathematics or pure mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 51021 THEORY OF MATRICES 3 Credit Hours

(Slashed with MATH 41021) A rigorous study of the topics introduced in matrix algebra. Topics included are: canonical forms of matrices, diagonalizability criteria.

Prerequisite: MATH 21001 and MATH 22005; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 51038 INTERMEDIATE LOGIC 3 Credit Hours

(Cross-listed with PHIL 51038)(Slashed with CS 41038, MATH 41038 and PHIL 41038) A detailed, systematic study of symbolic logic for philosophy majors, mathematics majors, computer science majors and anyone else interested in advanced study in logic. The aim of the course is twofold: (1) to develop a facility in understanding and using symbolic logic for various purposes, and (2) to understand and appreciate symbolic logic as an area of study in itself. Topics include the distinction between syntactic, object-level proofs and semantic, meta-level proofs; the distinction between axiomatic systems and natural deduction systems of object-level proofs; various systems of modal logic; and some non-classical logics.

Prerequisite: Graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52001 ANALYSIS I 3 Credit Hours

(Slashed with MATH 42001) Topics include basic structure of the real numbers, Cauchy sequences, convergence, completeness of the real numbers, continuity, differentiation and Riemann integration.

Prerequisite: Applied mathematics or pure mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52002 ANALYSIS II 3 Credit Hours

(Slashed with MATH 42002) Topics include further development of integration theory infinite series, uniform convergence, several variable calculus and metric spaces.

Prerequisite: MATH 42001 or MATH 52001; and applied mathematics or pure mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52011 MATHEMATICAL OPTIMIZATION 3 Credit Hours

(Slashed with MATH 42011) Analytical and numerical techniques for location of extreme points of functions and calculus of variations. Both constrained and unconstrained problems are considered.

Prerequisite: MATH 21001 and MATH 22005; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52021 GRAPH THEORY AND COMBINATORICS 3 Credit Hours

(Slashed with MATH 42021) Fundamentals and applications of combinatorial mathematics. Topics include transversability, colorability, networks, inclusion and exclusion, matching and designs.

Prerequisite: MATH 12003 and MATH 21001; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52024 NUMBERS AND GAMES 3 Credit Hours

(Slashed with MATH 42024) The study of partisan and impartial combinatorial games, games as numbers and Grundy-Sprague theory.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52031 MATHEMATICAL MODELS AND DYNAMICAL SYSTEMS 3 Credit Hours

(Slashed with MATH 42031) Formulation and analysis of mathematical models for a variety of phenomena. Mathematical methods from optimization, dynamical systems and probability are developed and applied. Modern software tools are utilized.

Prerequisite: MATH 32044; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52039 MODELING PROJECTS 3 Credit Hours

(Slashed with MATH 42039) Individual and small-group projects concerned with the formulation and analysis of mathematical models in a variety of areas. Written and oral reports required.

Prerequisite: MATH 52031 with a minimum C grade; and graduate standing.

Schedule Type: Seminar

Contact Hours: 3 other

Grade Mode: Standard Letter

MATH 52041 ADVANCED CALCULUS 3 Credit Hours

(Slashed with MATH 42041) The calculus and applications of scalar and vector functions of several variables. Vector differential and integral calculus. Applications to field theories, electricity and magnetism and fluid flow.

Prerequisite: MATH 21001 and MATH 22005.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52045 PARTIAL DIFFERENTIAL EQUATIONS 3 Credit Hours

(Slashed with MATH 42045) An introduction to Fourier series, Fourier transforms and partial differential equations. Wave, heat and potential equations of mathematical physics. Additional topics include Green's functions and the method of characteristics for wave equations.

Prerequisite: Applied Mathematics or Pure Mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52048 COMPLEX VARIABLES 3 Credit Hours

(Slashed with MATH 42048) Algebra of complex numbers, analytic functions, mappings, Cauchy integral theory, residue theory and applications.

Prerequisite: Applied mathematics or pure mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52201 NUMERICAL LINEAR ALGEBRA 3 Credit Hours

(Cross-listed with CS 52201)(Slashed with CS 42201 and MATH 42201) Fundamentals of numerical linear algebra; solving linear systems; QR factorization and least squares; iterative methods for eigenvalue problems.

Prerequisite: Applied Mathematics or Pure Mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 52202 NUMERICAL APPROXIMATION AND OPTIMIZATION 3 Credit Hours

(Cross-listed with CS 52202)(Slashed with CS 42202 and MATH 42202)

This course introduces numerical methods for solving nonlinear equations, optimizing functions, performing interpolation, computing differentiation and integration and solving differential equations.

Prerequisite: Applied Mathematics or Pure Mathematics major; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 55011 DIFFERENTIAL GEOMETRY 3 Credit Hours

(Slashed with MATH 45011) Analytic and metric differential geometry of curves and surfaces.

Prerequisite: MATH 22005; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 55021 EUCLIDEAN GEOMETRY 3 Credit Hours

(Slashed with MATH 45021) Geometry of Euclid extended to advanced topics of the triangle, quadrilaterals and circles: cross-ratio, groups, constructions, geometric generalizations and inversion.

Prerequisite: MATH 21001; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 55022 LINEAR GEOMETRY 3 Credit Hours

(Slashed with MATH 45022) Use of transformations as a tool to study geometry and to differentiate between different kinds of geometry. Linear algebra methods applied to geometry.

Prerequisite: MATH 21001; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 56001 ELEMENTARY TOPOLOGY 3 Credit Hours

(Slashed with MATH 46001) Metric spaces, introduction to topological spaces, separation axioms.

Prerequisite: MATH 22005; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 57011 THEORY OF NUMBERS 3 Credit Hours

(Slashed with MATH 47011) Divisibility properties of the integers, prime numbers, congruences, quadratic reciprocity, Diophantine equations, number theoretic functions, simple continued fractions and rational approximations.

Prerequisite: MATH 12003; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 57021 HISTORY OF MATHEMATICS 3 Credit Hours

(Slashed with MATH 47021) Survey from Babylonian and Egyptian mathematics to 20th-century mathematics with emphasis on the development of algebra, geometry, calculus, number theory.

Prerequisite: One course MATH 23022 or higher; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 57095 SPECIAL TOPICS: MATHEMATICS AND ITS APPLICATIONS 1-3 Credit Hours

(Repeatable for credit) Offered periodically with different topics and different faculty involved.

Prerequisite: Graduate standing or special approval.

Schedule Type: Lecture

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 59893 VARIABLE TITLE WORKSHOP IN MATHEMATICS 1-6 Credit Hours

(Repeatable for credit) Studies in special topics in pure and applied mathematics.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Workshop

Contact Hours: 1-6 other

Grade Mode: Satisfactory/Unsatisfactory

MATH 60051 PROBABILITY I 4 Credit Hours

(Slashed with MATH 70051) Distribution functions, measure theory, random variables, expectation, independence, convergence, concepts, law of large numbers.

Prerequisite: MATH 40011 or MATH 42002 or MATH 50011 or MATH 52002; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 60052 PROBABILITY II 3 Credit Hours

(Slashed with MATH 70052) Characteristic functions, the central limit problem, conditional expectations, Martingale theory, Brownian motion.

Prerequisite: MATH 60051; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 60061 MATHEMATICAL STATISTICS I 4 Credit Hours

(Slashed with MATH 70061) Statistics, distributions of statistics. Sampling distributions. Decision spaces and loss functions. Sufficiency and completeness. Estimation theory. Rao Blackwell and the Cramer Rao theorems.

Prerequisite: MATH 42002 or MATH 52002; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 60062 MATHEMATICAL STATISTICS II 3 Credit Hours

(Slashed with MATH 70062) Tests of statistical hypothesis. Neyman Pearson Lemma. Exponential families and invariance. Sequential tests. Non-parametric procedures.

Prerequisite: MATH 60061; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 60070 FINANCIAL MATHEMATICS 3 Credit Hours

(Slashed with MATH 70070) Topics from replication of trading strategies, arbitrage, completeness, Martingale representation theorem, fundamental theorem of finance, stochastic differential equations, Black and Scholes formula of option pricing.

Prerequisite: MATH 50051; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 60091 SEMINAR IN STATISTICS AND PROBABILITY 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in statistics and probability.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 60093 VARIABLE TITLE WORKSHOP IN MATHEMATICS 1-3 Credit Hours

(Repeatable for credit) Studies of special topics in mathematics. Not acceptable for credit toward a graduate degree in mathematics without approval of the student's adviser.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Workshop

Contact Hours: 1-3 other

Grade Mode: Satisfactory/Unsatisfactory

MATH 60194 COLLEGE TEACHING OF MATHEMATICS--LAB 1 Credit Hour

Techniques and problems in the teaching of college-level mathematics. Student presentations of mathematical papers and colloquia will be included.

Prerequisite: Graduate standing.

Schedule Type: Combined Lecture and Lab

Contact Hours: 0 lecture, 2 lab, 0 other

Grade Mode: Standard Letter

MATH 61051 ABSTRACT ALGEBRA I 4 Credit Hours

(Slashed with MATH 71051) Advanced topics in group theory including Sylow Theorems, finite Abelian groups, divisible groups and related concepts. Includes one hour problem session each week.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 61052 ABSTRACT ALGEBRA II 3 Credit Hours

(Slashed with MATH 71052) Advanced topics, commutative ring theory and field theory, including polynomial rings, unique factorization domains, matrix rings, Galois theory.

Prerequisite: MATH 61051; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 61091 SEMINAR IN ALGEBRA 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in algebra.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Satisfactory/Unsatisfactory

MATH 62041 METHODS OF APPLIED MATHEMATICS I 3 Credit Hours

(Slashed with MATH 72041) Analysis and applications of ordinary and partial differential equations and related topics. Dimensional analysis (Buckingham Pi Theorem). Perturbation methods (singular perturbations, matched asymptotic expansions, WKB approximation). Variational methods (Euler-Lagrange equations).

Prerequisite: MATH 51021 and MATH 52041 and MATH 52045 and MATH 52048; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62042 METHODS OF APPLIED MATHEMATICS II 3 Credit Hours

(Slashed with MATH 72042) Continuation of MATH 62041. Integral equations and Green's functions (Fredholm alternative, compact operators, distributions, weak solutions). Wave phenomena (dispersion, KdV equation). Stability and bifurcation (linearized stability analysis, turning points, Hopf bifurcation).

Prerequisite: MATH 62041; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62051 FUNCTIONS OF A REAL VARIABLE I 4 Credit Hours

(Slashed with MATH 72051) Introduction to modern concepts of real analysis, including metric spaces, measure and integration theory.

Prerequisite: MATH 42002 or MATH 52002; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 62052 FUNCTIONS OF A REAL VARIABLE II 3 Credit Hours

(Slashed with MATH 72052) A continuation of MATH 62051. Included are basic topics in functional analysis and Hilbert space theory.

Prerequisite: MATH 62051; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62151 FUNCTIONS OF A COMPLEX VARIABLE I 4 Credit Hours

(Slashed with MATH 72151) Topological properties of the complex plane; analytic, entire, meromorphic functions; analytic continuation; conformal mappings; Picard's Theorem; Riemann surfaces.

Prerequisite: MATH 52002; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 62152 FUNCTIONS OF A COMPLEX VARIABLE II 3 Credit Hours

(Slashed with MATH 72152) Topological properties of the complex plane; analytic, entire, meromorphic functions; analytic continuation; conformal mappings; Picard's Theorem; Riemann surfaces.

Prerequisite: MATH 62151; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62251 NUMERICAL ANALYSIS I 4 Credit Hours

(Slashed with MATH 72251) Floating point computation, rounding error analysis, conditioning, numerical solution of linear systems of equations (LU factorization, error analysis), least squares, orthogonalization methods, algebraic eigenvalue problems, QR algorithm, singular value decomposition.

Prerequisite: MATH 21001 or MATH 21002; and graduate standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 62252 NUMERICAL ANALYSIS II 3 Credit Hours

(Slashed with MATH 72252) Interpolation (polynomial, trigonometric, spline), numerical differentiation, numerical quadrature (Newton-Cotes, Gauss), extrapolation, Romberg integration, orthogonal polynomials, solving nonlinear equations and numerical optimization.

Prerequisite: MATH 22005; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62261 NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS 3 Credit Hours

(Slashed with MATH 72261) Discretization methods for ordinary differential equations and systems. Initial value and boundary value problems. Numerical implementation software and analysis.

Prerequisite: MATH 32044; and MATH 42202 or MATH 52202; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62262 NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS 3 Credit Hours

(Slashed with MATH 72262) Derivation and analysis of discrete methods (finite differences, finite elements) for the numerical solution of elliptic, hyperbolic and parabolic partial differential equations.

Prerequisite: MATH 42045 or MATH 52045; and MATH 42202 or MATH 52202; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62263 NUMERICAL SOLUTION OF LARGE SPARSE LINEAR SYSTEMS 3 Credit Hours

(Slashed with MATH 72263) Construction and analysis of iterative methods for large systems of linear algebraic equations. Jacobi, Gauss-Seidel, SOR. Polynomial acceleration methods, conjugate gradients. Multi-grid methods.

Prerequisite: MATH 41021 or MATH 51021; and MATH 42202 or MATH 52202; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62264 NUMERICAL SOLUTION OF NONLINEAR SYSTEMS 3 Credit Hours

(Slashed with MATH 72264) Construction and analysis of numerical methods for systems of nonlinear algebraic equations and optimization problems. Numerical implementation and software.

Prerequisite: MATH 42041 or MATH 52041; and MATH 42202 or MATH 52202; and graduate standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 62291 SEMINAR IN COMPUTATIONAL AND APPLIED MATHEMATICS 1-3 Credit Hours

(Repeatable for credit) (Slashed with MATH 72291) Seminar on current research in computational and applied Mathematics

Prerequisite: Graduate standing; and special approval.

Schedule Type: Seminar

Contact Hours: 3 other

Grade Mode: Standard Letter

MATH 62391 SEMINAR IN MEASURE THEORY 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in measure theory.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 62491 SEMINAR IN NONLINEAR ANALYSIS 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in nonlinear analysis.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 64091 SEMINAR IN MATHEMATICS EDUCATION 3 Credit Hours

(Repeatable for credit) Studies in geometry, algebra, mathematics for junior and senior high school. Mathematics content professionalized for teachers.

Prerequisite: MATH 34001; and graduate standing.

Schedule Type: Seminar

Contact Hours: 3 other

Grade Mode: Standard Letter

MATH 66051 INTRODUCTION TO TOPOLOGY I 4 Credit Hours

(Slashed with MATH 76051) Set theory, topological spaces, continuity, product spaces, quotient spaces, separation axioms, compactness and metrizable.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 67057 ADVANCED CONCEPTS OF GEOMETRY 3 Credit Hours

This course covers advanced topics in Euclidean geometry, including the Ceva's, Menelaus' and nine-point theorems; mass-point geometry; solid geometry; 2D and 3D analytic geometry; conic sections; geometric inequalities; applications of complex numbers in Euclidean geometry; geometric constructions; and combinatorial geometry.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 67067 ADVANCED CONCEPTS OF PROBABILITY AND STATISTICS 3 Credit Hours

This course covers advanced topics in probability and statistics, including core probability topics: probability axioms, discrete and continuous random variables, independence and conditional probability, inequalities and limit theorems; and main statistics topics sample, sample mean and variance, interval estimators, hypothesis tests and linear regression.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 67077 ADVANCED CONCEPTS OF ALGEBRA 3 Credit Hours

This course covers advanced topics in abstract algebra, including basic number theory; divisibility and congruence of integers; examples and properties of rings; polynomial rings; unique factorization and irreducibility of polynomials; quotient rings; finite fields; examples and basic properties of groups; Cayley tables and isomorphisms; subgroups; cosets; and the theorems of Lagrange, Euler and Fermat.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 67091 SEMINAR IN NUMBER THEORY 1-3 Credit Hours

(Repeatable for credit) (Slashed with MATH 77091) Seminar on current research in number theory.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 67095 SELECTED TOPICS IN MATHEMATICS 1-4 Credit Hours

(Repeatable for credit) Various special courses will be announced in the schedule of classes under this course number with different section numbers.

Prerequisite: Graduate standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-4 lecture, 0 lab, 0 other

Grade Mode: Standard Letter

MATH 67098 RESEARCH 1-15 Credit Hours

(Repeatable for credit) Research or individual investigation. Credits are applied toward degree requirements with approval if letter grade of "S" is given.

Prerequisite: Graduate standing.

Schedule Type: Research

Contact Hours: 1-15 other

Grade Mode: Standard Letter

MATH 67199 THESIS I 2-6 Credit Hours

Thesis student must register for a total of 6 hours, 2 to 6 hours in a single semester distributed over several semesters if desired.

Prerequisite: Graduate standing.

Schedule Type: Masters Thesis

Contact Hours: 2-6 other

Grade Mode: Satisfactory/Unsatisfactory-IP

MATH 67299 THESIS II 2 Credit Hours

Thesis students must continue registration each semester until all degree requirements are met.

Prerequisite: MATH 67199; and graduate standing.

Schedule Type: Masters Thesis

Contact Hours: 2 other

Grade Mode: Satisfactory/Unsatisfactory-IP

MATH 69099 CAPSTONE PROJECT 2-3 Credit Hours

The course is an integrative experience that brings together all components of the Masters nonthesis graduate program.

Prerequisite: Graduate standing and special approval.

Schedule Type: Project or Capstone

Contact Hours: 0 lecture, 0 lab, 2-3 other

Grade Mode: Standard Letter-IP

MATH 70051 PROBABILITY I 4 Credit Hours

(Slashed with MATH 60051) Distribution functions, measure theory, random variables, expectation, independence, convergence, concepts, law of large numbers.

Prerequisite: MATH 40011 or MATH 50011; or MATH 42002 or MATH 52002; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 70052 PROBABILITY II 3 Credit Hours

(Slashed with MATH 60052) Characteristic functions, the central limit problem, conditional expectations, Martingale theory, Brownian motion.

Prerequisite: MATH 60051 or MATH 70051; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 70061 MATHEMATICAL STATISTICS I 4 Credit Hours

(Slashed with MATH 60061) Statistics, distributions of statistics. Sampling distributions. Decision spaces and loss functions. Sufficiency and completeness. Estimation theory. Rao Blackwell and the Cramer Rao theorems.

Prerequisite: MATH 42002 or MATH 52002.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 70062 MATHEMATICAL STATISTICS II 3 Credit Hours

(Slashed with MATH 60062) Tests of statistical hypothesis. Neyman Pearson Lemma. Exponential families and invariance. Sequential tests. Non parametric procedures.

Prerequisite: MATH 60061 or MATH 70061; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 70070 FINANCIAL MATHEMATICS 3 Credit Hours

(Slashed with MATH 60070) Topics from replication of trading strategies, arbitrage completeness, Martingale presentation theorem, fundamental theorem of finance, stochastic differential equations, Black and Scholes formula of option pricing.

Prerequisite: MATH 50051; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 70091 SEMINAR IN STATISTICS AND PROBABILITY 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in statistics and probability.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Seminar

Contact Hours: 3 other

Grade Mode: Standard Letter

MATH 70095 SELECTED TOPICS IN STATISTICS AND PROBABILITY 1-3 Credit Hours

(Repeatable for credit) Topics vary with each offering and complement topics covered in MATH 70051, MATH 70052, MATH 70061 and MATH 70062.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 70194 COLLEGE TEACHING OF MATHEMATICS--LAB 1 Credit Hour

Techniques and problems in the teaching of college-level mathematics. Student presentations of mathematical papers and colloquia will be included.

Prerequisite: Graduate standing.

Schedule Type: Combined Lecture and Lab

Contact Hours: 0 lecture, 2 lab, 0 other

Grade Mode: Standard Letter

MATH 71001 STRUCTURE OF RINGS AND ALGEBRAS I 3 Credit Hours

Advanced topics in ring theory, including Artinian rings, Noetherian rings, advanced commutative ring theory.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 71002 STRUCTURE OF RINGS AND ALGEBRAS II 3 Credit Hours

Advanced topics in ring theory including an introduction to homological algebra. Includes Dedekind domains, regular rings, torsion theory.

Prerequisite: MATH 71001; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 71011 ADVANCED GROUP THEORY 3 Credit Hours

Advanced topics in group theory. Topics include permutation arguments, coprime actions, transfer theorems, nonsimplicity criteria. Properties of families of groups: solvable, p solvable, nilpotent, p groups.

Prerequisite: MATH 61051 or MATH 71051; and MATH 61052 or MATH 71052; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 71012 CHARACTERS OF FINITE GROUPS 3 Credit Hours

Development of characters of finite groups, their properties, orthogonality relations, integrality conditions. Applications include Burnside's paqb theorem and existence of Frobenius kernels in Frobenius groups.

Prerequisite: MATH 61051 or MATH 71051; and MATH 61052 or MATH 71052; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 71051 ABSTRACT ALGEBRA I 4 Credit Hours

(Slashed with MATH 61051) Advanced topics in group theory, including Sylow theorems, finite Abelian groups, divisible groups and related concepts. Includes one-hour problem session each week.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 71052 ABSTRACT ALGEBRA II 3 Credit Hours

(Slashed with MATH 61052) Advanced topics, commutative ring theory and field theory, including polynomial rings, unique factorization, domains, matrix rings, Galois theory.

Prerequisite: MATH 61051 or MATH 71051; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 71091 SEMINAR IN ALGEBRA 1-3 Credit Hours

(Repeatable for credit) (Slashed with MATH 61091) Seminar on current research in algebra.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Satisfactory/Unsatisfactory

MATH 71095 SELECTED TOPICS IN ALGEBRA 1-3 Credit Hours

(Repeatable for credit) Topics vary with each offering and complement topics covered in MATH 71002, MATH 71051 and MATH 71052.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 72001 FUNCTIONAL ANALYSIS I 3 Credit Hours

A study of principles of linear analysis in the setting of normed linear spaces and topological vector spaces.

Prerequisite: MATH 72052; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72041 METHODS OF APPLIED MATHEMATICS I 3 Credit Hours

(Slashed with MATH 62041) Analysis and applications of ordinary and partial differential equations and related topics. Dimensional analysis (Buckingham Pi Theorem). Perturbation methods (singular perturbations, matched asymptotic expansions, WKB approximation). Variational methods (Euler-Lagrange equations).

Prerequisite: MATH 51021 and MATH 52041 and MATH 52045 and MATH 52048; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72042 METHODS OF APPLIED MATHEMATICS II 3 Credit Hours

(Slashed with MATH 62042) Continuation of MATH 72041. Integral equations and Green's functions (Fredholm alternative, compact operators, distributions, weak solutions). Wave phenomena (dispersion, KdV equation). Stability and bifurcation (linearized stability analysis, turning points, Hopf bifurcation).

Prerequisite: MATH 62041 or MATH 72041; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72051 FUNCTIONS OF A REAL VARIABLE I 4 Credit Hours

(Slashed with MATH 62051) Introduction to modern concepts of real analysis including metric spaces, measure and integration theory.

Prerequisite: MATH 42002 or MATH 52002; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 72052 FUNCTIONS OF A REAL VARIABLE II 3 Credit Hours

(Slashed with MATH 62052). A continuation of MATH 72051. Included are basic topics in functional analysis and Hilbert space theory.

Prerequisite: MATH 62051 or MATH 72051; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72095 SELECTED TOPICS IN REAL ANALYSIS 1-3 Credit Hours

(Repeatable for credit) Topics vary with each offering and complement topics covered in MATH 72002, MATH 72051 and MATH 72052.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 72151 FUNCTIONS OF A COMPLEX VARIABLE I 4 Credit Hours

(Slashed with MATH 62151) Topological properties of the complex plane; analytic, entire, meromorphic functions; analytic continuation; conformal mappings; Picard's Theorem; Riemann surfaces.

Prerequisite: MATH 52002; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 72152 FUNCTIONS OF A COMPLEX VARIABLE II 3 Credit Hours

(Slashed with MATH 62152) Topological properties of the complex plane; analytic, entire, meromorphic functions; analytic continuation; conformal mappings; Picard's theorem; Riemann surfaces.

Prerequisite: MATH 72151; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72195 SELECTED TOPICS IN COMPLEX ANALYSIS 1-3 Credit Hours

(Repeatable for credit) Topics vary with each offering and complement topics covered in MATH 72151 and MATH 72152.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 72251 NUMERICAL ANALYSIS I 4 Credit Hours

(Slashed with MATH 62251) Floating point computation, rounding error analysis, conditioning, numerical solution of linear systems of equations (LU factorization, error analysis), least squares, orthogonalization methods, algebraic eigenvalue problems, QR algorithm, singular value decomposition.

Prerequisite: MATH 21001 or MATH 21002; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 72252 NUMERICAL ANALYSIS II 3 Credit Hours

(Slashed with MATH 62252) Interpolation (polynomial, trigonometric, spline), numerical differentiation, numerical quadrature (Newton-Cotes, Gauss), extrapolation, Romberg integration, orthogonal polynomials, solving nonlinear equations and numerical optimization.

Prerequisite: MATH 22005; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72261 NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS 3 Credit Hours

(Slashed with MATH 62261) Discretization methods for ordinary differential equations and systems. Initial value and boundary value problems. Numerical implementation software and analysis.

Prerequisite: MATH 32044; and MATH 42202 or MATH 52202; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72262 NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS 3 Credit Hours

(Slashed with MATH 62262) Derivation and analysis of discrete methods (finite differences, finite elements) for the numerical solution of elliptic, hyperbolic and parabolic partial differential equations.

Prerequisite: MATH 42045 or MATH 52045; and MATH 42202 or MATH 52202; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72263 NUMERICAL SOLUTION OF LARGE SPARSE LINEAR SYSTEMS 3 Credit Hours

(Slashed with MATH 62263) Construction and analysis of iterative methods for large systems of linear algebraic equations. Jacobi, Gauss-Seidel, SOR. Polynomial acceleration methods, conjugate gradients. Multi-grid methods.

Prerequisite: MATH 41021 or MATH 51021; and MATH 42202 or MATH 52202; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72264 NUMERICAL SOLUTION OF NONLINEAR SYSTEMS 3 Credit Hours

(Slashed with MATH 62264) Construction and analysis of numerical methods for systems of nonlinear algebraic equations and optimization problems. Numerical implementation and software.

Prerequisite: MATH 42041 or MATH 52041; and MATH 42202 or MATH 52202; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 72291 SEMINAR IN COMPUTATIONAL AND APPLIED MATHEMATICS 1-3 Credit Hours

(Repeatable for credit) (Slashed with Math 62291) Seminar on current research in numerical analysis.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 72295 SELECTED TOPICS IN NUMERICAL ANALYSIS 1-3 Credit Hours

(Repeatable for credit) Topics vary with each offering and complement topics covered in MATH 72251 and MATH 72252.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 72391 SEMINAR IN MEASURE THEORY 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in measure theory.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 72491 SEMINAR IN NONLINEAR ANALYSIS 1-3 Credit Hours

(Repeatable for credit) Seminar on current research in nonlinear analysis.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 76051 INTRODUCTION TO TOPOLOGY I 4 Credit Hours

(Slashed with MATH 66051) Set theory, topological spaces, continuity, product spaces, quotient spaces separation axioms, compactness and metrizable.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 4 lecture

Grade Mode: Standard Letter

MATH 76095 SELECTED TOPICS IN TOPOLOGY 1-3 Credit Hours

(Repeatable for credit) Topics vary with each offering and complement topics covered in MATH 76051.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 77011 ALGEBRAIC NUMBER THEORY 3 Credit Hours

Number fields and Dedekind domains; conjugates, norm and trace, discriminant, integral bases; arithmetic or quadratic and cyclotomic number fields; theory of ideals and class group; Dirichlet's theorem on units.

Prerequisite: MATH 57011; and MATH 61052 or MATH 71052; and doctoral standing.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 77012 ANALYTIC NUMBER THEORY 3 Credit Hours

Multiplicative functions and summatory functions, Riemann's Zeta function and the prime number theorem, L-functions and Dirichlet's theorem on primes in arithmetic progressions, asymptotic formula for partitions.

Prerequisite: MATH 57011 and MATH 62151 or MATH 72151.

Schedule Type: Lecture

Contact Hours: 3 lecture

Grade Mode: Standard Letter

MATH 77091 SEMINAR IN NUMBER THEORY 1-3 Credit Hours

(Repeatable for credit) (Slashed with MATH 67091) Seminar on current research in number theory.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Seminar

Contact Hours: 1-3 other

Grade Mode: Standard Letter

MATH 77095 SELECTED TOPICS IN MATHEMATICS 1-3 Credit Hours

(Repeatable for credit) Course topic varies with each offering.

Prerequisite: Special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 77098 RESEARCH I 1-15 Credit Hours

(Repeatable for credit) Research or individual investigation. Credits are applied toward degree requirements with approval if letter grade of "S" is given.

Prerequisite: Doctoral standing.

Schedule Type: Research

Contact Hours: 1-15 other

Grade Mode: Standard Letter

MATH 77195 SELECTED TOPICS IN NUMBER THEORY 1-3 Credit Hours

(Repeatable for credit) Content varies with each offering and complements topics covered in MATH 77011 and MATH 77012.

Prerequisite: Doctoral standing; and special approval.

Schedule Type: Lecture

Contact Hours: 1-3 lecture

Grade Mode: Standard Letter

MATH 77198 RESEARCH II 1-15 Credit Hours

(Repeatable for credit) Research or individual investigation. Credits are applied toward degree requirements with approval if letter grade of "S" is given.

Prerequisite: Doctoral standing.

Schedule Type: Research

Contact Hours: 1-15 other

Grade Mode: Satisfactory/Unsatisfactory

MATH 87098 RESEARCH 1-15 Credit Hours

(Repeatable for credit) Research or individual investigation for doctoral students who have not yet passed their candidacy examinations. Credits earned may be applied toward degree if department approves.

Prerequisite: Doctoral standing.

Schedule Type: Research

Contact Hours: 1-15 other

Grade Mode: Standard Letter

MATH 87199 DISSERTATION I 15 Credit Hours

(Repeatable for credit) Doctoral dissertation, for which registration in at least two semesters is required first of which will be semester in which dissertation work is begun and continuing until the completion of 30 hours.

Prerequisite: Admission to doctoral candidacy; and doctoral standing.

Schedule Type: Dissertation

Contact Hours: 15 other

Grade Mode: Satisfactory/Unsatisfactory-IP

MATH 87299 DISSERTATION II 15 Credit Hours

(Repeatable for credit) Continuing registration required of doctoral students who have completed the initial 30 hours of dissertation and continuing until all degree requirements are met.

Prerequisite: MATH 87199; and doctoral standing.

Schedule Type: Dissertation

Contact Hours: 15 other

Grade Mode: Satisfactory/Unsatisfactory-IP