COMPUTATIONAL APPLIED MATHEMATICS AND OPERATIONS RESEARCH (CMOR)

CMOR 220 - INTRODUCTION TO ENGINEERING COMPUTATION
Short Title: INTRO TO ENG COMPUTATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Modeling, Simulation, and Visualization using Matlab and Python. This project-based course introduces students to engineering computation in Matlab and Python. Computational projects motivated by different science and engineering applications are used to introduce basic numerical methods, and develop computational solutions using Matlab and Python. No programming knowledge is required or expected; students learn how to implement their solutions in Matlab and Python. Lectures are held Mondays and Wednesdays. In a laboratory component held on Fridays, students work in small groups on computational projects led by a Rice Learning Assistant. Fall/Spring semester: meeting 3 times per week (50min each meeting). Summer semester: meeting 5 times per week (65min each meeting) OR refer to the current schedule. Recommended Prerequisite(s): MATH 101 or MATH 105

CMOR 238 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Activity Course, Intensive Learning Experience, Independent Study, Internship/Practicum, Laboratory, Lecture, Lecture/Laboratory, Research, Seminar, Studio
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

CMOR 302 - MATRIX ANALYSIS
Short Title: MATRIX ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Equilibria and the solution of linear systems and linear least squares problems. Eigenvalue problem and its application to solve dynamical systems. Singular value decomposition and its application. Recommended Prerequisite(s): (MATH 212 or MATH 222) and (CAAM 210 or CMOR 220 or COMP 140)

CMOR 303 - MATRIX ANALYSIS FOR DATA SCIENCE
Short Title: MATRIX ANALYSIS DATA SCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Solution of linear systems and linear least squares problems. Eigenvalue problem and singular value decomposition. Introduction to gradient based methods. Applications to data science. Recommended Prerequisite(s): (MATH 212 or MATH 222) and (CAAM 210 or CMOR 220 or COMP 140 or STAT 405)

CMOR 304 - DIFFERENTIAL EQUATIONS IN SCIENCE AND ENGINEERING
Short Title: DIFF EQUATIONS SCI & ENG
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Classical and numerical solution techniques for ordinary and partial differential equations. Fourier series and the finite element method for initial and boundary value problems arising in diffusion and wave propagation phenomena. Recommended Prerequisite(s): (MATH 212 or MATH 222) AND (CAAM 210 or CMOR 220) AND (CMOR 302 OR CMOR 303 OR MATH 355 OR MATH 354) AND (MATH 211 OR MATH 220)

CMOR 350 - STOCHASTIC MODELS
Short Title: STOCHASTIC MODELS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ECON 307 or STAT 310 or STAT 311 or STAT 315
Description: Fundamentals of stochastic modeling in engineering and operations research. Topics include discrete-time Markov chains, Poisson processes, birth-and-death processes and other continuous-time Markov chains, renewal processes, with applications in applications in queueing, inventory, finance, healthcare, and epidemics. Recommended Prerequisite(s): MATH 212 and (CAAM 210 or CMOR 220 or COMP 140) and (CAAM 335 or CMOR 302 or MATH 355)

CMOR 360 - INTRODUCTION TO OPERATIONS RESEARCH AND OPTIMIZATION
Short Title: INTRO TO O.R. AND OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Formulation of mathematical models of complex decisions arising in management, economics, and engineering. Models using linear, nonlinear, stochastic and integer programming, as well as networks. Linear programming duality and its modeling implications. Overview of basic solution methods for these optimization models. Recommended Prerequisite(s): MATH 212 and (CAAM 334 or CMOR 303 or CAAM 335 or CMOR 302 or MATH 211 or MATH 355) and (CAAM 210 or CMOR 220 or COMP 140)

CMOR 404 - GRAPH THEORY
Short Title: GRAPH THEORY
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Study of the structure and properties of graphs, together with a variety of applications. Includes paths, cycles, trees, connectivity, matchings, colorings, planarity, directed graphs, and algorithms. Some knowledge of linear algebra is recommended. Graduate/Undergraduate Equivalency: CMOR 504.

CMOR 405 - PARTIAL DIFFERENTIAL EQUATIONS I
Short Title: PARTIAL DIFFERENTIAL EQNS I
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: First order of partial differential equations. The method of characteristics. Analysis of the solutions of the wave equation, heat equation and Laplace's equation. Integral relations and Green's functions. Potential theory, Dirichlet and Neumann problems. Asymptotic methods: the method of stationary phase, geometrical optics, regular and singular perturbation methods. Cross-list: MATH 423. Graduate/Undergraduate Equivalency: CMOR 505. Recommended Prerequisite(s): MATH 321 AND MATH 322 Mutually Exclusive: Cannot register for CMOR 405 if student has credit for CMOR 505.

CMOR 410 - MODELING MATHEMATICAL PHYSICS
Short Title: MODELING MATHEMATICAL PHYSICS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Derivation and properties of solutions of the partial differential equations of continuum physics. Basic concepts of continuum mechanics, ideal fluids, Navier-Stokes equations, linear elasticity, acoustics, basic principles of thermodynamics, Newtonian heat flow, porous flow, Maxwell's equations, electrical circuits. Graduate/Undergraduate Equivalency: CMOR 510. Recommended Prerequisite(s): (CAAM 336 or CMOR 304)

CMOR 415 - THEORETICAL NEUROSCIENCE: FROM CELLS TO LEARNING SYSTEMS
Short Title: THEORETICAL NEUROSCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 102 or MATH 106) and (MATH 211 or MATH 220 or CMOR 304)
Description: This course presents the theoretical foundations of cellular and systems neuroscience from a quantitative perspective, integrating mathematical modeling, computational tools, and data analysis. Students will develop and apply differential equations, probabilistic models, and reverse correlation techniques to analyze neural activity and synaptic interactions. The course combines traditional lectures with student-led presentations in a seminar-style format. Coursework includes problem sets, coding-based assignments, and group projects. MATLAB or Python proficiency is strongly recommended. Cross-list: ELEC 488, NEUR 415. Graduate/Undergraduate Equivalency: CMOR 615. Recommended Prerequisite(s): This course requires coding in MATLAB or Python. As such, COMP 140, CMOR 220 or some equivalent coding experience is highly recommended. Mutually Exclusive: Cannot register for CMOR 415 if student has credit for CMOR 615.

CMOR 416 - NEURAL COMPUTATION
Short Title: NEURAL COMPUTATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Course Level: Undergraduate Upper-Level
Description: How does the brain work? Understanding the brain requires sophisticated theories to make sense of the collective actions of billions of neurons and trillions of synapses. Word theories are not enough; we need mathematical theories. The goal of this course is to provide an introduction to the mathematical theories of learning and computation by neural systems. These theories use concepts from dynamical systems (attractors, oscillations, chaos) and concepts from statistics (information, uncertainty, inference) to relate the dynamics and functions of neural networks. We will apply these theories to sensory computation, learning and memory, and motor control. Students will learn to formalize and mathematically answer questions about neural computations, including “what does a network compute?”, “how does it compute?”, and “why does it compute that way?” Prerequisites: knowledge of calculus, linear algebra, and probability and statistics. Cross-list: ELEC 489, NEUR 416.

CMOR 417 - SCIENTIFIC MACHINE LEARNING
Short Title: SCIENTIFIC MACHINE LEARNING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 304 and (CMOR 303 or CMOR 302)
Description: Introduction to scientific machine learning and its application to physical problems. Mathematical and numerical models of physical systems are integrated with machine learning approaches to develop physics-based or numerics-based data-driven methods for the solution of science and engineering problems. Graduate/Undergraduate Equivalency: CMOR 517. Mutually Exclusive: Cannot register for CMOR 417 if student has credit for CMOR 517.

CMOR 420 - COMPUTATIONAL SCIENCE
Short Title: COMPUTATIONAL SCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Scientific programming using high level languages, including C, Fortran, and C++. Emphasis on use of numerical libraries. Basic techniques of project planning, source management, documentation, program construction, i/o, visualization. Object-oriented design for numerical computing. Grading and assignments would be different between the 400/500 level. Graduate/Undergraduate Equivalency: CMOR 520. Recommended Prerequisite(s): (CAAM 210 or CMOR 220 and CAAM 335 or CMOR 302) or (CAAM 453 or CMOR 422)

CMOR 421 - HIGH PERFORMANCE COMPUTING
Short Title: HIGH PERFORMANCE COMPUTING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Theory and application of the message passing interface for programming scientific computing applications. Introduction to the architecture and programming of multicore and massively parallel processors, including general purpose graphics processing units, Insight for designing efficient numerical algorithms to improve parallelization of memory access and utilization of non-uniform memory architectures. Application interfaces include OpenMP, MPI, CUDA, OpenCL, and parallel numerical algorithm libraries. Grading and assignments would be different between the 400/500 level. Graduate/Undergraduate Equivalency: CMOR 521. Recommended Prerequisite(s): (CAAM 419 or CMOR 420)

CMOR 422 - NUMERICAL ANALYSIS
Short Title: NUMERICAL ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CAAM 334 or CMOR 303 or CAAM 335 or CMOR 302
Description: Construction and application of numerical algorithms for root finding, interpolation and approximation of functions, quadrature, and the solution of differential equations; fundamentals of computer arithmetic; solution of linear systems, linear least squares problems, and eigenvalue problems via matrix factorizations; Newton and Newton-like methods for nonlinear systems of equations. Computer programming in MATLAB is required. Graduate/Undergraduate Equivalency: CMOR 522.

CMOR 423 - NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Short Title: NUMERICAL METHODS FOR PDES
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Course Level: Undergraduate Upper-Level
Description: This course covers various numerical methods for solving partial differential equations: aspects of finite difference methods, finite element methods, finite volume methods, mixed methods, discontinuous Galerkin methods, and meshless methods. Both theoretical convergence and practical implementation of the methods are studied for elliptic and parabolic problems. Cross-list: CEVE 455. Graduate/Undergraduate Equivalency: CMOR 523. Recommended Prerequisite(s): CAAM 336 or CMOR 304 Mutually Exclusive: Cannot register for CMOR 423 if student has credit for CMOR 523.

CMOR 428 - COMPUTATIONAL DIFFERENTIAL EQUATIONS
Short Title: COMP DIFF EQUATIONS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to the implementation of computational methods for solving model partial differential equations: diffusion, heat equation and Stokes equations. The finite difference methods, finite element methods and finite volume methods are studied for two dimensional homogeneous and inhomogeneous domains. Time integrators are the forward Euler, backward Euler and Crank-Nicolson methods. Graduate/Undergraduate Equivalency: CMOR 528. Mutually Exclusive: Cannot register for CMOR 428 if student has credit for CMOR 528.

CMOR 430 - ITERATIVE METHODS FOR SYSTEMS OF EQUATIONS AND UNCONSTRAINED OPTIMIZATION
Short Title: SYST OF EQNS & UNCONST OPTIM
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Iterative methods for linear systems of equations including Krylov subspace methods, including the conjugate gradient method and GMRES; gradient and Newton-like methods for unconstrained optimization and nonlinear least squares problems; Newton and Newton-like methods for nonlinear systems of equations; techniques for improving the global convergence of these algorithms; implementation of these methods in Matlab or Python; applications to example problems in science and engineering. Graduate/Undergraduate Equivalency: CMOR 530. Recommended Prerequisite(s): (CAAM 453 or CMOR 422)

CMOR 435 - DYNAMICAL SYSTEMS
Short Title: DYNAMICAL SYSTEMS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Course Level: Undergraduate Upper-Level
Description: Existence and uniqueness for solutions of ordinary differential equations and difference equations, linear systems, nonlinear systems, stability, periodic solutions, bifurcation theory. Theory and theoretical examples are complemented by computational, model driven examples from biological and physical sciences. Cross-list: MATH 435. Recommended Prerequisite(s): (MATH 212 or MATH 221) and (CAAM 335 or MATH 355 or MATH 354) and (MATH 302 or MATH 321 or MATH 331)
Course URL: math.rice.edu (http://math.rice.edu)

CMOR 437 - OPTIMIZATION FOUNDATIONS OF DATA SCIENCE
Short Title: OPT FOUND OF DATA SCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 360
Description: Optimization methods for machine learning. Topics included are as follows: basics of optimization theory, gradient-based optimization (e.g., gradient descent, stochastic gradient descents, AdaGrad, Adam, RMSProp, etc.), linear regression and its extensions (e.g., ridge regression and lasso), least-squares classification and logistic regression, Newton methods in machine learning, basics of constrained optimization, Lagrangian relaxation and duality, support vector machines, and optimization in neural networks.

CMOR 438 - DATA SCIENCE AND MACHINE LEARNING
Short Title: DATA SCI & MACHINE LEARNING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Fundamentals of data science and machine learning. Topics include: introduction to scikit-learn, Keras and tensorflow2, linear and logistic regression, clustering, support vector machines, random forest trees, neural networks, deep learning, natural language processing. Graduate/Undergraduate Equivalency: INDE 577. Mutually Exclusive: Cannot register for CMOR 438 if student has credit for INDE 577.

CMOR 441 - LINEAR AND INTEGER PROGRAMMING
Short Title: LINEAR AND INTEGER PROGRAMMING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 302 or MATH 321 or MATH 331) and (CAAM 335 or CMOR 302 or CMOR 303 or MATH 355 or MATH 354)
Description: This course provides a rigorous introduction to linear optimization with continuous and integral variables. We explore the theory and algorithms of linear and integer programming. Topics studied in the linear programming part include polyhedral theory, duality, and algorithms for solving linear programs. Building on linear programming, the second part of this course studies linear optimization with integral variables. Here, the topics covered are integral polyhedra and perfect formulations, including TU matrices and TDI systems. We culminate with exact methodologies for integer programming, including branch-and-bound and cutting-plane techniques. This course provides the foundations for further studies in convex optimization, combinatorial optimization, and stochastic programming. Graduate/Undergraduate Equivalency: CMOR 541. Recommended Prerequisite(s): CAAM 378 or CMOR 360

CMOR 442 - LARGE-SCALE OPTIMIZATION
Short Title: LARGE-SCALE OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 441 and COMP 140 and (CMOR 302 or CMOR 303 or MATH 354 or MATH 355)
Description: Decomposition of large-scale linear, nonlinear and integer programs. Minkowski representation of polyhedra. Benders' and Dantzig-Wolfe decomposition. Relaxations, including Lagrangian relaxation. Examples include multicommodity flow and stochastic linear programs. Design and testing of computational strategies for difficult optimization problems. Students will implement projects in Python. Graduate/Undergraduate Equivalency: INDE 546.

CMOR 444 - DISCRETE OPTIMIZATION
Short Title: DISCRETE OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 360
Description: Discrete optimization broadly involves finding the best solution from a finite set of possibilities in a computationally efficient manner. Subfields like combinatorial optimization and integer programming are especially popular in industry applications, such as routing deliveries for e-commerce platforms and scheduling virtual machines for cloud companies. In this course, we will explore common discrete problems encountered in practical applications, such as minimum spanning trees, max/min flows, maximum matchings, and scheduling problems. We will analyze the discrete structures underlying these problems and develop algorithms for finding optimal or near-optimal solutions. We will also introduce linear and integer programming to tackle discrete problems. The course will also cover computational complexity and the approximation of several hard problems. Recommended Prerequisite(s): A linear algebra course and COMP 140

CMOR 446 - GRAPH ALGORITHMS
Short Title: GRAPH ALGORITHMS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Graph Algorithms in Operations Research. Topics include: spanning trees, graph search algorithms, shortest path problems, worst case time complexity analysis, computational complexity, dominating set problems, vertex and edge cover problems, python implementations, and other problems in graph optimization. Instructor Permission Required. Graduate/Undergraduate Equivalency: INDE 511. Recommended Prerequisite(s): CMOR 360 and COMP 182 Mutually Exclusive: Cannot register for CMOR 446 if student has credit for INDE 511.

CMOR 451 - SIMULATION MODELING AND ANALYSIS
Short Title: SIM MODELING AND ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 350
Description: This course introduces simulation techniques that uses statistical sampling, probability models and computational tools to study complex stochastic systems arising in service operations, healthcare, telecommunications, production, logistics, inventory and financial systems. Topics covered include generating random objects (random variables and stochastic processes, discrete-event systems), input and output analysis, steady-state simulation, variance-reduction methods, rare-event simulation, Markov chain Monte Carlo methods, and simulation-based optimization. The course lectures are supplemented with programming components in homework and projects. Graduate/Undergraduate Equivalency: CMOR 551. Recommended Prerequisite(s): MATH 212, (STAT 310 or STAT 311 or STAT 418), (CAAM 334 or 303 or CAAM 335 or CMOR 302), and MATH 302

CMOR 452 - SERVICE SYSTEMS ANALYTICS
Short Title: SERVICE SYS ANALYTICS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 360
Corequisite: CMOR 350
Description: This course provides a broad exploration of large-scale service systems using data analytics, stochastic models, optimization and simulation techniques. In particular, through the data collection, preparation, visualization and analysis, students will understand the demand and service processes. Through the optimization and stochastic models and simulations, students will formulate decisions problems to determine optimal capacity (workforce and other resources) and resource allocations to meet the in the long-term and short-term horizons. Applying these modeling and analytical techniques and tools, students will conduct case studies in modern service systems such as healthcare, on-demand service systems, transportation and recreational services.

CMOR 455 - STOCHASTIC CONTROL AND APPLICATIONS
Short Title: STOCHASTIC CONTROL & APP
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 350
Description: Stochastic control theory and applications in a variety of areas including dynamic resource allocation, finance, inventory, queueing and stochastic networks, and epidemiology. Topics include foundations of stochastic control for Markov processes and diffusions, maximum principle, dynamic programming and Hamilton-Jacobi-Bellman (HJB) equations, finite-horizon and infinite-horizon discounted and average problems, optimal stopping problem, impulse control, risk sensitive control, differential games, viscosity solutions, iteration and policy iteration and other numerical solution algorithms. Graduate/Undergraduate Equivalency: CMOR 555. Recommended Prerequisite(s): Equivalent of advanced course work in calculus (e.g., MATH 212, 221, or 232), statistics and probability theory (e.g., STAT 310 or STAT 311, STAT 315), linear algebra (e.g., CMOR 302, 303, MATH 354, or MATH 355) and analysis (e.g., MATH 302, 321 or 331), and differential equations (e.g., MATH 211 or CMOR 304).

CMOR 461 - LOGISTICS AND SUPPLY CHAIN MANAGEMENT
Short Title: LOG & SUPPLY CHAIN MANAGEMENT
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Inventory management: EOQ, newsvendor, reorder point order quantity, multi-echelon models. Scheduling, distribution & location models. Vehicle routing problems. Supply chain coordination. Sustainability in supply chains. Graduate/Undergraduate Equivalency: INDE 561. Recommended Prerequisite(s): STAT 310 (Probability & Statistics) or STAT 315 (Statistics for Data Sciences); CMOR 360 Intro to OR and Optimization

CMOR 462 - OPTIMIZATION METHODS IN FINANCE
Short Title: OPT METHODS IN FINANCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CAAM 378 or CMOR 360
Description: Portfolio optimization and asset allocation models. Risk management and option pricing. Deterministic and stochastic optimization approaches, as well as linear and nonlinear approaches will be used to model decisions arising in finance. Graduate/Undergraduate Equivalency: INDE 567.

CMOR 463 - OPERATIONS RESEARCH IN HEALTHCARE
Short Title: OPER RES IN HEALTHCARE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Operations research in healthcare systems and medical decision-making. Application areas will include hospital resource management, patient scheduling, treatment planning and organ transplantation. Modeling techniques will include mathematical programming, stochastic processes, Markov decision processes and simulation. Graduate/Undergraduate Equivalency: INDE 513. Recommended Prerequisite(s): CMOR 350, CMOR 360 Mutually Exclusive: Cannot register for CMOR 463 if student has credit for INDE 513.

CMOR 464 - MANUFACTURING PROCESSES AND SYSTEMS
Short Title: MANUFACTURING PROC AND SYS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Fundamentals of manufacturing processes and systems. Topics include basic factory dynamics, benchmarking, design and control of single-stage production systems, queueing network approximations for multi-stage production systems, analysis of flow lines and job shops, push & pull systems, impact of variability in manufacturing processes, lean manufacturing. Instructor Permission Required. Recommended Prerequisite(s): CMOR 350

CMOR 465 - REVENUE MANAGEMENT & PRICING
Short Title: REVENUE MGMT & PRICING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Ever wondered why airfares change? Why a person in the seat next to yours got a better deal or perhaps why you were able to fly to your desired destination for pennies? And, why airlines often ask whether you are willing to take another flight in exchange for a voucher? The above are just one sort of examples where prices for travel services seem to change for reasons that are not immediately clear. People have been intrigued about these practices and with the advent of the already ubiquitous e-commerce prices that change dynamically are part of everyday life. Revenue management ('RM') and dynamic pricing are the science engines that power that dynamic. In this course we will study both theory and practice of revenue management and dynamic pricing with a focus on its application areas. The goal is to find a scientifically sound answer to the question of what product a firm should offer to a customer at any given time, given capacity constraints and, possibly, some other information. This economics problem has often been paraphrased as 'selling the right product to the right customer at the right price' and has become acute in thin-margin industries such as airlines (after deregulation in the 70's), where even a small improvement in revenue implies a major improvement to profit. Several early adopters in other industries having similar features followed shortly, e.g., hotels, cruise lines, and car rental companies. The wealth of information and the ease of modifying customer offering that came with the advent of the Internet spurred an incredible expansion in the number of industries adopting the discipline of RM and gave rise to several closely related areas of new techniques and applications such as dynamic pricing, offer optimization, multi-sided markets (e.g. ride-sharing platforms, online auctions) and other aspects of e-commerce. Graduate/Undergraduate Equivalency: INDE 565. Recommended Prerequisite(s): STAT 310 (Probability & Statistics) or STAT 315 (Statistics for Data Sciences); MATH 212 (Multivariate Calculus); CMOR 360 Intro to OR and Optimization Mutually Exclusive: Cannot register for CMOR 465 if student has credit for INDE 565.

CMOR 467 - OPTIMIZATION FOR ENERGY SYSTEMS
Short Title: OPTIMIZATION FOR ENERGY SYSTEM
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is aimed towards advanced undergraduate, masters, and PhD students to the forefront of energy systems research. The focus is on understanding and addressing key decision-making and optimization problems associated with electric power system modeling and optimization and its interactions with other infrastructure systems. Graduate/Undergraduate Equivalency: CMOR 567. Recommended Prerequisite(s): CMOR 302 or CMOR 303 or CMOR 360 Mutually Exclusive: Cannot register for CMOR 467 if student has credit for CMOR 567.

CMOR 477 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Activity Course, Intensive Learning Experience, Independent Study, Internship/Practicum, Laboratory, Lecture, Lecture/Laboratory, Research, Seminar, Studio
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

CMOR 490 - UNDERGRADUATE RESEARCH PROJECTS
Short Title: UNDERGRAD RESEARCH PROJECTS
Department: Comp Appl Math Operations Rsch
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Semester-long undergraduate-level research on a topic in computational and applied mathematics and/or operations research. Instructor Permission Required. Repeatable for Credit.

CMOR 491 - UNDERGRADUATE RESEARCH PROJECTS
Short Title: UNDERGRAD RESEARCH PROJECTS
Department: Comp Appl Math Operations Rsch
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Semester-long undergraduate-level research on a topic in computational and applied mathematics and/or operations research. Instructor Permission Required. Repeatable for Credit.

CMOR 492 - SENIOR DESIGN PROJECT I
Short Title: SENIOR DESIGN PROJECT I
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 2
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Students engage in team-oriented year-long design projects that utilize modeling, analysis, and scientific computing skills to solve a problem motivated by an application in engineering or the physical, biological, or social sciences. Participants attend regular seminars addressing research techniques and effective written and verbal presentation of mathematics.

CMOR 493 - SENIOR DESIGN PROJECT II
Short Title: SENIOR DESIGN PROJECT II
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 2
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 492
Description: Continuation of CMOR 492. Seminars focus on the presentation of results from design groups and provide guidance on the composition of a substantial project report.

CMOR 494 - PEDAGOGY FOR CMOR 220 RICE LEARNING ASSISTANTS
Short Title: PEDAGOGY FOR RLAS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 2
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is designed to support Rice Learning Assistants (RLAs) as they instruct their own lab sections of CMOR 220. Topics include analysis of computational science and engineering concepts, issues of problem-based learning (PBL), theories of learning, and fundamental teaching skills. Required for CMOR 220 RLAs. Instructor Permission Required. Repeatable for Credit.

CMOR 495 - LOSING THE PRECIOUS FEW
Short Title: LOSING THE PRECIOUS FEW
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The class will read from Tapia's text: Losing the Precious Few: How America Fails to Educate Minorities in Science and Engineering and then discuss in class issues associated with the underrepresentation of Blacks and Hispanics in academic and national science and engineering activities. Topics will include racism, immigration, student admissions, faculty hiring, faculty promotion, the role of minority serving institutions, mistaking foreign minorities for the Precious Few, support issues and leadership.

CMOR 496 - COMPUTATIONAL AND APPLIED MATHEMATICS SEMINAR
Short Title: COMP & APPLIED MATH SEMINAR
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course prepares a student for research in the mathematical sciences on a specific topic. Each section is dedicated to a different topic. Current topics include eigenvalues, model reduction, combinatorial optimization, optimization algorithms, scientific computing, and numerical analysis. The topics may vary each semester. Graduate/Undergraduate Equivalency: CMOR 696. Repeatable for Credit.

CMOR 500 - ANALYSIS
Short Title: ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Real numbers, completeness, sequences and convergence, compactness, continuity, the derivative, the Riemann integral, fundamental theorem of calculus. Vector spaces, dimension, linear maps, inner products and norms, derivatives in R^d, inverse function theorem, implicit function theorem, multiple integration, change of variable theorem. Instructor Permission Required.

CMOR 501 - APPLIED FUNCTIONAL ANALYSIS
Short Title: APPLIED FUNCTIONAL ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Hilbert spaces, Banach spaces, spectral theory, and weak topologies with applications to signal processing, control, and partial differential equations. Biennial; Offered in Odd Years. Recommended Prerequisite(s): MATH 322

CMOR 504 - GRAPH THEORY
Short Title: GRAPH THEORY
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Study of the structure and properties of graphs, together with a variety of applications. Includes paths, cycles, trees, connectivity, matchings, colorings, planarity, directed graphs, and algorithms. Some knowledge of linear algebra is recommended. This course covers the same lecture material as CMOR 404, but fosters greater theoretical sophistication through more challenging problem sets and exams on the graduate side. Graduate/Undergraduate Equivalency: CMOR 404.

CMOR 505 - PARTIAL DIFFERENTIAL EQUATIONS I
Short Title: PARTIAL DIFFERENTIAL EQNS I
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: First order of partial differential equations. The method of characteristics. Analysis of the solutions of the wave equation, heat equation and Laplace's equation. Integral relations and Green's functions. Potential theory, Dirichlet and Neumann problems. Asymptotic methods: the method of stationary phase, geometrical optics, regular and singular perturbation methods. Additional course work is required beyond the undergraduate course requirements. Cross-list: MATH 513. Graduate/Undergraduate Equivalency: CMOR 405. Recommended Prerequisite(s): MATH 321 AND MATH 322 Mutually Exclusive: Cannot register for CMOR 505 if student has credit for CMOR 405.

CMOR 507 - APPLIED AND COMPUTATIONAL MICROLOCAL AND HARMONIC ANALYSIS
Short Title: MICROLOCAL & HARMONIC ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CAAM 423 or CMOR 405
Description: Introduction to microlocal and harmonic analysis. Oscillatory integrals, Wavefront set, Pseudodifferential and Fourier Integral Operators and their calculus, and basic symplectic geometry. Egorov's theorem and propagation of singularities. Wavepackets, matrix classes and discretization; USFFT and fast curvelet transform. Parametrix construction for wave equations and applications in imaging. Recommended Prerequisite(s): MATH 302, (CAAM 334 or CMOR 303 or CAAM 335 or CMOR 302), MATH 401, (CAAM 453 or CMOR 422), MATH 522.

CMOR 508 - NONLINEAR SYSTEMS: ANALYSIS AND CONTROL
Short Title: NONLINEAR SYSTEMS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Mathematical background and fundamental properties of nonlinear systems: Vector norms, matrix norms, matrix measures, existence and uniqueness of solutions of ordinary differential equations. Linearization, second order systems, periodic solutions, approximate methods. Lyapunov stability: Stability definitions, Lyapunov's direct method, invariance theory, stability of linear systems, Lyapunov's linearization method, converse theorems. Selected topics in nonlinear systems analysis and nonlinear control from: Input/Output stability: Small gain theorem, passivity theorem. Perturbation theory, averaging, and singular perturbations Feedback linearization control. Other methods in the control of nonlinear systems such as backstepping, sliding mode and other Lyapunov-based design methods. Advanced nonlinear and adaptive robot control. Cross-list: ELEC 508, MECH 508.

CMOR 510 - MODELING MATHEMATICAL PHYSICS
Short Title: MODELING MATHEMATICAL PHYSICS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course combines basic physical principles with vector calculus to derive many important partial differential equations governing motion of fluids and solids. Topics include stress, strain, idealized fluids, linear elasticity, acoustics, basics of thermodynamics, Navier-Stokes. Graduate/Undergraduate Equivalency: CMOR 410. Recommended Prerequisite(s): (CAAM 336 or CMOR 304).

CMOR 514 - INDUSTRIAL AND APPLIED DATA SCIENCE – THEORY AND PRACTICE
Short Title: INDUSTRIAL & APPLIED DATA SCI
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This graduate-level course presents a pragmatic introduction to the foundational theory of data science along with a series of practical skills for working data scientists. It includes modern aspects of data science driven by massively more data and computer power such as deep neural networks, reinforcement learning and the principles of generative AI. The course is supplemented by practical programming exercises to be completed every week by all students. Industrial-strength applications of data science in the energy sector, from image and text processing to physics-based simulations are discussed in appropriate detail, along with how the enterprise value gets delivered in practice. How does data science relate to MLOps, how do data science teams work, how quickly will skillsets need updating? Recommended Prerequisite(s): Equivalent of advanced course work in computer programming (e.g. COMP 321), calculus (e.g. MATH 212), statistics or probability theory, linear algebra (e.g. CAAM 334 or CMOR 303 or CAAM 335 or CMOR 302). Proficiency in MATLAB (course programming language) or Python (alternative to MATLAB available to course participants).

CMOR 517 - SCIENTIFIC MACHINE LEARNING
Short Title: SCIENTIFIC MACHINE LEARNING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to scientific machine learning and its application to physical problems. Mathematical and numerical models of physical systems are integrated with machine learning approaches to develop physics-based or Numerics-based data-driven methods for the solution of science and engineering problems. Graduate/Undergraduate Equivalency: CMOR 417. Mutually Exclusive: Cannot register for CMOR 517 if student has credit for CMOR 417.

CMOR 518 - APPLICATIONS IN COMPUTATIONAL MATHEMATICS
Short Title: APPLICATIONS IN COMP MATH
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students. Enrollment limited to students in a Master of Comp & Appl Math, Master of Comp Sci & Eng, Master of Computer Science, Master of Data Science, Master of Electrical Comp Eng, Master of Eng Mgmt & Leadershp, Master of Industrial Eng, Master of Mechanical Eng or Master of Statistics degrees.
Course Level: Graduate
Description: Introduction to fundamental tools in computational mathematics and their application to science and engineering problems using Python. Topics include tools from linear algebra for data compression, least squares, and dynamical systems; modeling and simulation using ordinary differential equations; approximation and interpolation of functions; gradient-based methods for parameter estimation.

CMOR 520 - COMPUTATIONAL SCIENCE
Short Title: COMPUTATIONAL SCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Scientific programming using high level languages, including C, Fortran, and C++. Emphasis on use of numerical libraries. Basic techniques of project planning, source management, documentation, program construction, i/o, visualization. Object-oriented design for numerical computing. Grading and assignments would be different between the 400/500 level. Graduate/Undergraduate Equivalency: CMOR 420. Recommended Prerequisite(s): (CAAM 210 or CMOR 220 and CAAM 335 or CMOR 302) or (CAAM 453 or CMOR 422)

CMOR 521 - HIGH PERFORMANCE COMPUTING
Short Title: HIGH PERFORMANCE COMPUTING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Theory and application of the message passing interface for programming scientific computing applications. Introduction to the architecture and programming of multicore and massively parallel processors, including general purpose graphics processing units, Insight for designing efficient numerical algorithms to improve parallelization of memory access and utilization of non-uniform memory architectures. Application interfaces include OpenMP, MPI, CUDA, OpenCL, and parallel numerical algorithm libraries. Grading and assignments would be different between the 400/500 level. Graduate/Undergraduate Equivalency: CMOR 421. Recommended Prerequisite(s): (CAAM 519 or CMOR 520)

CMOR 522 - NUMERICAL ANALYSIS
Short Title: NUMERICAL ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Construction and application of numerical algorithms for root finding, interpolation and approximation of functions, quadrature, and the solution of differential equations; fundamentals of computer arithmetic; solution of linear systems, linear least squares problems, and eigenvalue problems via matrix factorizations; Newton and Newton-like methods for nonlinear systems of equations. Computer programming in MATLAB is required. Graduate/Undergraduate Equivalency: CMOR 422.

CMOR 523 - NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Short Title: NUMERICAL METHODS FOR PDES
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers various numerical methods for solving partial differential equations: aspects of finite difference methods, finite element methods, finite volume methods, mixed methods, discontinuous Galerkin methods, and meshless methods. Both theoretical convergence and practical implementation of the methods are studied for elliptic and parabolic problems. May receive credit for only one of the following courses: CAAM 452/CEVE 455/CAAM 536/CEVE 555. Cross-list: CEVE 555. Graduate/Undergraduate Equivalency: CMOR 423. Recommended Prerequisite(s): CAAM 336 or CMOR 304 Mutually Exclusive: Cannot register for CMOR 523 if student has credit for CMOR 423.

CMOR 524 - ADVANCED NUMERICAL ANALYSIS
Short Title: ADV NUMERICAL ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Corequisite: CMOR 500
Description: Construction and analysis of numerical algorithms for root finding, interpolation and approximation of functions, quadrature, and the solution of differential equations; fundamentals of computer arithmetic; solution of linear systems, least squares problems, and eigenvalue problems via matrix factorizations; the singular value decomposition (SVD) and basic sensitivity analysis. Computer programming in MATLAB is required. This course covers fewer topics than CAAM 453 with greater theoretical depth. Instructor Permission Required.

CMOR 525 - NUMERICAL LINEAR ALGEBRA
Short Title: NUMERICAL LINEAR ALGEBRA
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Iterative methods for solving linear systems: Jacobi, Gauss-Seidel, geometric multigrids, p-multigrids, algebraic multigrids. Connection between multigrid methods and some special architectures of neural networks. Randomized methods for matrix computations: randomized matrix matrix multiplications, randomized SVD, randomized least squares and QR. Recommended Prerequisite(s): (CAAM 453 or CMOR 422 or CAAM 550 or CMOR 522 or CAAM 553 or CMOR 524)

CMOR 526 - FOUNDATIONS OF FINITE ELEMENT METHODS
Short Title: FINITE ELEMENT METHODS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course addresses the theory and implementation of finite element methods. Topics include weak solutions of partial differential equations, Sobolev spaces, approximation theory, convergence and reliability of the numerical methods. Continuous and discontinuous finite element methods are considered.

CMOR 527 - DISCONTINUOUS GALERKIN METHODS FOR SOLVING ENGINEERING PROBLEMS
Short Title: DISCONTINUOUS GALERKIN METHODS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course will present the theory and implementation of discontinuous Galerkin methods for partial differential equations common in engineering applications. Two main classes of problems are covered: steady-state and time-dependent elliptic/parabolic and hyperbolic equations. These include (but are not limited to) the Poisson and heat equations, linear wave equations, and nonlinear conservation laws. Recommended Prerequisite(s): (CAAM 336 or CMOR 304 or CAAM 453 or CMOR 422 or CAAM 553 or CMOR 524)

CMOR 528 - COMPUTATIONAL DIFFERENTIAL EQUATIONS
Short Title: COMP DIFF EQUATIONS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to the implementation of computational methods for solving model partial differential equations: diffusion, heat equation and Stokes equations. The finite difference methods, finite element methods and finite volume methods are studied for two dimensional homogeneous and inhomogeneous domains. Time integrators are the forward Euler, backward Euler and Crank-Nicolson methods. Graduate/Undergraduate Equivalency: CMOR 428. Mutually Exclusive: Cannot register for CMOR 528 if student has credit for CMOR 428.

CMOR 530 - ITERATIVE METHODS FOR SYSTEMS OF EQUATIONS AND UNCONSTRAINED OPTIMIZATION
Short Title: SYST OF EQNS & UNCONST OPTIM
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers the same lecture material as CMOR 430, but fosters greater theoretical sophistication through more challenging problem sets and exams. Graduate/Undergraduate Equivalency: CMOR 430. Recommended Prerequisite(s): (CAAM 550 or CMOR 522) or (CAAM 553 or CMOR 524).

CMOR 531 - CONVEX OPTIMIZATION
Short Title: CONVEX OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Convex optimization problems arise in communication, system theory, VLSI, CAD, finance, inventory, network optimization, computer vision, learning, statistics, etc., even though oftentimes convexity may be hidden and unrecognized. Recent advances in interior-point methodology have made it much easier to solve these problems and various solvers are now available. This course will introduce the basic theory and algorithms for convex optimization, as well as its many applications to computer science, engineering, management science and statistics. Biennial; Offered in Odd Years. Recommended Prerequisite(s): (CAAM 335 or CMOR 302 and MATH 321)

CMOR 532 - OPTIMIZATION THEORY
Short Title: OPTIMIZATION THEORY
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Derivation and application of necessity conditions and sufficiency conditions for constrained optimization problems.

CMOR 533 - NUMERICAL OPTIMIZATION
Short Title: NUMERICAL OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Numerical algorithms for constrained optimization problems in engineering and sciences, including simplex and interior-point methods for linear programming, penalty, barrier, augmented Lagrangian and SQP methods for nonlinear programming. Recommended Prerequisite(s): CAAM 560 or CMOR 532 (may be taken concurrently) and CAAM 454 or CMOR 430).

CMOR 534 - INTRO TO PARTIAL DIFFERENTIAL EQUATION BASED SIMULATION AND OPTIMIZATION
Short Title: PDE SIMULATION AND OPTIM
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (CAAM 501 or CMOR 500) and (CAAM 553 or CMOR 524)
Description: Introduction to the theory and numerical methods for the solution of elliptic partial differential equations (PDEs) and optimization problems governed by these PDEs. Topics include functional analysis, well-posedness of elliptic problems, optimality conditions for PDE constrained optimization problems and finite element discretizations. Recommended Prerequisite(s): (CAAM 554 or CMOR 530)

CMOR 536 - OPTIMIZATION WITH SIMULATION CONSTRAINTS
Short Title: OPTIMIZATION W/SIM CONSTRAINTS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Optimization problems in which evaluations of objective or constraint functions require computationally complex simulations arise in many engineering and science applications in the form of optimal design, optimal control, or parameter identification problems. This course introduces optimization approaches to solve these complex problems, and their application to engineering and science problems. Topics include derivative based optimization methods for problems with inexact function and derivative information, derivative approximations for functions involving computationally complex simulations, generation and use of surrogate models in optimization, derivative free optimization methods. Recommended Prerequisite(s): (CAAM 554 or CMOR 530 or CAAM 564 or CMOR 533)

CMOR 537 - COMPUTER-ASSISTED ALGORITHM DESIGN FOR OPTIMIZATION AND MACHINE LEARNING
Short Title: COMPUTER-ASSISTED ALG DESIGN
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CMOR 531 or CMOR 532 or CMOR 533 or CMOR 536 or INDE 517 or INDE 577
Description: In a traditional first course in continuous optimization, students learn to use and analyze existing algorithms, such as applying Stochastic Gradient Descent to train neural networks, using Accelerated Gradient Descent to solve image processing problems, or study their convergence analysis. In contrast, this course methodically addresses the fundamental questions: Where do these algorithms come from? How do we know they are any good? And, most importantly, could we design something provably better? The core of this course is a transition from merely using and analyzing optimization algorithms to actively designing them, treating the algorithm design process itself as an optimization problem. The goal is to construct algorithms that are the provably fastest methods for specific classes of problems in consideration. In particular, we will focus on designing the optimal first-order methods (FOMs), which are methods that rely solely on gradient or subgradient information. These are the most commonly used optimization algorithms today, given their efficacy in solving high-dimensional problems, compatibility with large-scale datasets, and applicability to machine learning. The curriculum is structured in two main parts. First, we will learn to build a mathematical model (an optimization problem in itself) that calculates the absolute worst-case performance for a given algorithm. This provides a rigorous framework for computing tight convergence guarantees for a known algorithm. Subsequently, we will formulate the search for the provably fastest algorithm as a new, higher-level optimization problem. The solution to this problem is, in fact, the optimal algorithm we seek. This modern, computer-assisted approach to algorithm design is known as Performance Estimation Problem (PEP). This is a hands-on course with a strong emphasis on implementation, where students will learn to build the tools that discover these algorithms from scratch using PEP. By the end, students will not only understand the theory behind cutting-edge algorithm design but will also have the skills to discover and analyze new, high-performance algorithms for a variety of challenges in optimization and data science.

CMOR 541 - LINEAR AND INTEGER PROGRAMMING
Short Title: LINEAR AND INTEGER PROGRAMMING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers the same lecture material as CMOR 441, but fosters greater theoretical sophistication through more challenging problem sets and exams. Graduate/Undergraduate Equivalency: CMOR 441.

CMOR 543 - COMBINATORIAL OPTIMIZATION
Short Title: COMBINATORIAL OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: General theory and approaches for solving combinatorial optimization problems are studied. Specific topics include basic polyhedral theory, minimum spanning trees, shortest paths, network flow, matching and matroids. The course also covers the traveling salesman problem.

CMOR 544 - STOCHASTIC OPTIMIZATION
Short Title: STOCHASTIC OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CAAM 571 or CMOR 541
Description: Stochastic optimization models arise in many contexts. This course focuses on stochastic programs, including stochastic integer programs and multi-stage stochastic programs. It will emphasize the interplay between theory and computational approaches.

CMOR 551 - SIMULATION MODELING AND ANALYSIS
Short Title: SIM MODELING AND ANALYSIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces simulation techniques that uses statistical sampling, probability models and computational tools to study complex stochastic systems arising in service operations, healthcare, telecommunications, production, logistics, inventory and financial systems. Topics covered include generating random objects (random variables and stochastic processes, discrete-event systems), input and output analysis, steady-state simulation, variance-reduction methods, rare-event simulation, Markov chain Monte Carlo methods, and simulation-based optimization. The course lectures are supplemented with programming components in homework and projects. Graduate/Undergraduate Equivalency: CMOR 451.

CMOR 552 - MATHEMATICAL PROBABILITY I
Short Title: MATHEMATICAL PROBABILITY I
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Measure-theoretic foundations of probability. Open to qualified undergraduates. Required for PhD students in statistics. Cross-list: STAT 581.

CMOR 553 - INTRODUCTION TO RANDOM PROCESSES AND APPLICATIONS
Short Title: INTRO RANDOM PROCESSES & APPL
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Review of basic probability; Sequences of random variables; Random vectors and estimation; Basic concepts of random processes; Random processes in linear systems, expansions of random processes; Wiener filtering; Spectral representation of random processes, and white-noise integrals. Cross-list: ELEC 533, STAT 583.

CMOR 554 - APPLIED STOCHASTIC PROCESSES
Short Title: APPLIED STOCHASTIC PROCESSES
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): STAT 518 or CMOR 500
Description: This course covers the theory of some of the most frequently used stochastic processes in application: Poisson and renewal processes, discrete-time and continuous-time Markov chains, martingales, Brownian motion and diffusion processes. Cross-list: STAT 552.

CMOR 555 - STOCHASTIC CONTROL AND APPLICATIONS
Short Title: STOCHASTIC CONTROL & APP
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Stochastic control theory and applications in a variety of areas including dynamic resource allocation, finance, inventory, queueing and stochastic networks, and epidemiology. Topics include foundations of stochastic control for Markov processes and diffusions, maximum principle, dynamic programming and Hamilton-Jacobi-Bellman (HJB) equations, finite-horizon and infinite-horizon discounted and average problems, optimal stopping problem, impulse control, risk sensitive control, differential games, viscosity solutions, iteration and policy iteration and other numerical solution algorithms. Graduate/Undergraduate Equivalency: CMOR 455. Recommended Prerequisite(s): Equivalent of advanced course work in calculus (e.g., MATH 212), statistics and probability theory (e.g., STAT 310 or STAT 311, STAT418), linear algebra (e.g., CAAM 334 or CAAM 345) and analysis (e.g., MATH302), and differential equations.

CMOR 556 - STOCHASTIC NETWORKS AND QUEUEING SYSTEMS
Short Title: STOCH NTWRKS & QUEUEING SYS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Stochastic networks and queueing systems in a variety of applications including service systems engineering, logistics, telecommunications, manufacturing, transportation and data centers. Topics include fundamental queueing models (Markovian, non-Markovian, single-server or multi-server) and stochastic networks, performance analysis and approximations, fluid and diffusion models under heavy traffic, simulation, optimal control (scheduling and routing) of stochastic network models.

CMOR 567 - OPTIMIZATION FOR ENERGY SYSTEMS
Short Title: OPTIMIZATION FOR ENERGY SYSTEM
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is aimed towards the forefront of energy systems research. The focus is on understanding and addressing key decision-making and optimization problems associated with electric power system modeling and optimization and its interactions with other infrastructure systems. Graduate/Undergraduate Equivalency: CMOR 467. Recommended Prerequisite(s): CMOR 441/541 or CMOR 442 Mutually Exclusive: Cannot register for CMOR 567 if student has credit for CMOR 467.

CMOR 590 - GRADUATE RESEARCH PROJECTS
Short Title: GRADUATE RESEARCH PROJECTS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Semester-long graduate-level research on a topic in computational and applied mathematics and/or operations research. Instructor Permission Required. Repeatable for Credit.

CMOR 591 - GRADUATE RESEARCH PROJECTS
Short Title: GRADUATE RESEARCH PROJECTS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Semester-long graduate-level research on a topic in computational and applied mathematics and/or operations research. Instructor Permission Required. Repeatable for Credit.

CMOR 595 - PRACTICUM IN COMPUTATIONAL APPLIED MATHEMATICS AND OPERATIONS RESEARCH
Short Title: PRACTICUM IN CMOR
Department: Comp Appl Math Operations Rsch
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Internship/Practicum
Credit Hours: 1,2
Restrictions: Enrollment is limited to Graduate level students. Enrollment limited to students in a Master of Comp & Appl Math, Master of Comp Sci & Eng or Master of Industrial Eng degrees.
Course Level: Graduate
Description: This course is restricted to graduate students in degree programs administered by the Department of Computational Applied Mathematics and Operations Research (CMOR). This course introduces current theoretical and applied problems in the practice of Computational Applied Mathematics and Operations Research through practical internships. Students will be required to complete a paid or unpaid off-campus internship. Students will be required to submit a written, 5-10 page report summarizing the experience developed during the internship, as well documenting how the internship was instrumental to the student's course of study. This course is repeatable for credit, but the total number of CAAM 595 credits that can be applied to a specific degree program, may be limited by that degree program. Instructor Permission Required. Repeatable for Credit.

CMOR 600 - THESIS WRITING
Short Title: THESIS WRITING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Assists the student in preparation of the MA/PhD thesis and in other writing projects. Structure of a scientific paper, effective approaches to technical writing, building literature review, results, and discussion sections, how to write a good abstract, oral presentation skills. Prerequisite: Advisor approval of topic and consent of the instructor(s). Instructor Permission Required. Repeatable for Credit.

CMOR 615 - THEORETICAL NEUROSCIENCE I: BIOPHYSICAL MODELING OF CELLS AND CIRCUITS
Short Title: THEORETICAL NEUROSCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course presents the theoretical foundations of cellular and systems neuroscience from a quantitative perspective, integrating mathematical modeling, computational tools, and data analysis. Students will develop and apply differential equations, probabilistic models, and reverse correlation techniques to analyze neural activity and synaptic interactions. The course combines traditional lectures with student-led presentations in a seminar-style format. Coursework includes problem sets, coding-based assignments, and group projects. MATLAB or Python proficiency is strongly recommended. Cross-list: ELEC 588, NEUR 615. Graduate/Undergraduate Equivalency: CMOR 415. Mutually Exclusive: Cannot register for CMOR 615 if student has credit for CMOR 415.

CMOR 618 - TOPICS IN SEISMIC IMAGING
Short Title: TOPICS IN SEISMIC IMAGING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Content varies from year to year. Instructor Permission Required. Repeatable for Credit.

CMOR 619 - TOPICS IN INVERSE PROBLEMS
Short Title: TOPICS IN INVERSE PROBLEMS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Theoretical, computational and practical issues for inverse problems in science and engineering. Selected topics will vary depending on instructor and student interests. Instructor Permission Required. Repeatable for Credit.

CMOR 620 - TOPICS IN COMPUTATIONAL SCIENCE
Short Title: TOPICS COMPUTATIONAL SCIENCE
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Content varies from year to year. Repeatable for Credit.

CMOR 623 - TOPICS IN NUMERICAL DIFFERENTIAL EQUATIONS
Short Title: TOPICS IN NUM DIFF EQNS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Content varies from year to year. Instructor Permission Required. Repeatable for Credit.

CMOR 625 - TOPICS IN NUMERICAL LINEAR ALGEBRA
Short Title: TOPICS IN NUM LINEAR ALGEBRA
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Selected topics will vary depending on instructor and student interests. Derivation and analysis of Krylov and subspace iteration methods for large eigenvalue problems (Lanczos, Arnoldi, Jacobi-Davidson algorithms); preconditioning for linear systems and eigenvalue problems (incomplete LU, domain decomposition, multigrid); convergence analysis including potential theory and pseudospectra. Applications: regularization of discrete inverse problems; dimension reduction for large dynamical control systems; effects on non-normality on behavior of dynamical systems and iterative processes. Instructor Permission Required. Recommended Prerequisite(s): CAAM 551 or CMOR 525 Repeatable for Credit.

CMOR 636 - TOPICS IN NONLINEAR PROGRAMMING
Short Title: TOPICS NONLINEAR PROGRAMMING
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Content varies from year to year. Instructor Permission Required. Repeatable for Credit.

CMOR 646 - TOPICS IN OPTIMIZATION
Short Title: TOPICS IN OPTIMIZATION
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Content varies from year to year. Instructor Permission Required. Repeatable for Credit.

CMOR 677 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Activity Course, Intensive Learning Experience, Independent Study, Internship/Practicum, Laboratory, Lecture, Lecture/Laboratory, Research, Seminar, Studio
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

CMOR 696 - COMPUTATIONAL AND APPLIED MATHEMATICS SEMINAR
Short Title: COMP & APPLIED MATH SEMINAR
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 1-9
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course prepares a student for research in the mathematical sciences on a specific topic. Each section is dedicated to a different topic. Current topics include bioinformatics, biomathematics, computational finance, simulation driven optimization, data simulation, and spectral optimization in rational mechanics. The topics may vary each semester. Instructor Permission Required. Graduate/Undergraduate Equivalency: CMOR 496. Repeatable for Credit.

CMOR 800 - RESEARCH AND THESIS
Short Title: RESEARCH AND THESIS
Department: Comp Appl Math Operations Rsch
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is for MA or PhD students working on their thesis research. Repeatable for Credit.