

# DEPARTMENT OF STATISTICS AND OPERATIONS RESEARCH (GRAD)

## Contact Information

### Department of Statistics and Operations Research

Visit Program Website (<http://stat-or.unc.edu>)

The Department offers the master of science (M.S.) and doctor of philosophy (Ph.D.) in statistics and operations research (STOR). The M.S. degree is a single program (MS-STOR). The Ph.D. degree can be earned in one of three programs: statistics (STAT), operations research (OR), and interdisciplinary statistics and operations research (INSTORE).

The MS-STOR program is intended for students who wish to pursue careers in data science and analytics or as a preparation for continuing on to further graduate studies in related areas. This program focuses on training students in advanced quantitative thinking due to the increasing demand for skills in data-driven decision making in the modern world. It is possible for motivated students to complete the requirements in three semesters, though the typical duration is four. For students graduating with an undergraduate STAN degree, there is also an option of 5-year MS-STOR program.

The Ph.D. degree in STOR is designed for students planning a career in teaching or research. This degree requires at least three (but usually five) years of full-time graduate study, predicated upon substantial undergraduate mathematical preparation. Research is a central component in the work of doctoral candidates. Research training consists of required core coursework as well as electives that are designed to bring students up to date in their research field and intensive one-on-one work with a faculty member on a specific dissertation topic. Doctoral students who want to pursue academic careers are provided with ample opportunities to teach introductory undergraduate courses, and they are given extensive training to develop their instructional skills. Doctoral students may also participate in paid internships with local industrial employers to gain experience in a business environment. Their professional skills are further enhanced by work on real-world projects with clients in the department's consulting courses. Several courses provide opportunities for students to give technical presentations and refine their communication skills.

Further information on the graduate degree programs can be obtained from the department's Web site (<https://stat-or.unc.edu/programs>).

### Admissions and Financial Aid

Admission to the department is highly competitive, and preference is given to applicants who are solidly prepared. Although the department welcomes promising students from all disciplines, entering students must have a substantial mathematical background and applicants must satisfy the entrance requirements of The Graduate School. A student admitted with a deficiency in any area must make up for it at the beginning of her or his graduate work. If the deficiency is not severe, this can be accomplished without interrupting the normal program.

Application form (<http://gradschool.unc.edu/admissions>)

Students can indicate on this application form (<http://gradschool.unc.edu/admissions>) whether they intend to pursue the

M.S. degree program or a Ph.D. in one of these three programs: OR, STAT, or INSTORE.

Funding basics (<https://gradschool.unc.edu/funding/basics/fundingbasics.html>) including links for Financial Aid are provided by The Graduate School.

Most of our Ph.D. students receive some form of financial support, such as Graduate School fellowships, departmental assistantships, research assistantships, or internships. Departmental assistantships involve grading or teaching an undergraduate course. Some of our students are supported as research assistants by faculty. Our supported students receive a tuition waiver, and health insurance for the duration of their studies.

## Ph.D. Program in Operations Research

Operations research is concerned with the process of decision making for the purpose of optimal resource allocation. The spectrum of related activities includes basic research in optimization theory, development of deterministic and stochastic mathematical models as aids for decision making, and application of these models to real-world problems. The principal steps in modeling consist of analyzing relationships that determine the probable future consequences of decision choices and then devising appropriate measures of effectiveness in order to evaluate the relative merits of alternative actions. During the past 50 years, operations research has developed as a mathematical science whose methods of analysis are regularly employed in many diverse industries and governmental agencies.

## Ph.D. Program in Statistics

The Ph.D. program in statistics provides students with a broad-based course of study in applied statistics, theoretical statistics, and probability, as well as numerous advanced topic courses. The breadth and depth of the program has served graduates well in their subsequent careers in academia, industry, and government. Doctoral students pursue a wide range of dissertation research, ranging from applied statistics to theoretical probability. Many students are involved in interdisciplinary research that puts them in regular contact with faculty and students in other departments at UNC, and in some cases, other institutions. Past interactions with other units at UNC have included Environmental Sciences, Biology, the Lineberger Comprehensive Cancer Center, Computer Science, Biostatistics, Economics, and the Carolina Center for Genome Sciences.

## Ph.D. Program in INSTORE

The Ph.D. program entitled interdisciplinary statistics and operations research (INSTORE) was established in the fall semester of 2007. The INSTORE program is suitable for students pursuing an interdisciplinary research agenda who want to combine elements from the traditional statistics and operations research programs. The INSTORE program allows flexibility for adaptively combining statistics and operations research. However, there are specific tracks that contain suggested sequences of courses allowing students to focus on certain areas of study.

## Degree Requirements

### M.S. STOR Program

The statistics M.S. degree requires 30 credit hours of coursework and the completion of a master's project. Students can choose from a variety of courses, including a limited number from outside the department.

Upon approval of The Graduate School, at most six credit hours may be transferred from another accredited institution or from within UNC–Chapel Hill for courses taken before admission to the M.S. program.

## Ph.D. Program

The Ph.D. degree requires at least 45 semester hours of graduate coursework and the successful completion of a doctoral dissertation. Detailed information about specific courses, elective courses and allowable courses outside of the STOR department for each program are provided on the graduate admissions section of the program's Web site (<http://stat-or.unc.edu/programs/statistics/phd>).

## Statistics Courses for Students From Other Disciplines

A number of STOR courses in probability and statistics are of potential interest to students in other disciplines. At the advanced undergraduate/beginning graduate level, STOR 455 and STOR 556, provide an introduction to applied statistics, including regression, analysis of variance, and time series. STOR 435 and STOR 555 provide introductions to probability theory and mathematical statistics, respectively, at a postcalculus level.

The three graduate course sequences—(STOR 664, STOR 665), (STOR 654, STOR 655), and (STOR 634, STOR 635)—provide comprehensive introductions to modern applied statistics, theoretical statistics, and probability theory, respectively, at a more mathematical level. In each case it is possible to take only the first course in the sequence. Concerning mathematical prerequisites, STOR 664 and STOR 665 require a background in linear algebra and matrix theory, while the remaining courses require a solid background in real analysis.

*Following the faculty member's name is a section number that students should use when registering for independent studies, reading, research, and thesis and dissertation courses with that particular professor.*

## Professors

**Nilay Argon (1)**, Stochastic Models, Manufacturing and Healthcare Applications, Discrete Event Simulation  
**Amarjit Budhiraja (2)**, Probability, Stochastic Analysis, Large Deviations  
**Edward Carlstein (3)**, Nonparametric Statistics, Resampling  
**Jan Hannig (14)**, Statistics, Fiducial Inference, Stochastic Processes  
**Vidyadhar G. Kulkarni (6)**, Stochastic Models of Queues, Healthcare Systems, Supply Chains, Telecommunication Systems, Warranties  
**Yufeng Liu (8) Carolina Center for Genome Sciences**, Statistical Machine Learning, Data Mining, Bioinformatics, Experimental Designs  
**James Stephen Marron (10)** (Amos Hawley Distinguished Professor), Object-Oriented Data Analysis, Visualization, Smoothing  
**Andrew Nobel (11)**, Machine Learning, Data Mining, Computational Genomics  
**Vladas Pipiras (13)**, Time Series and Spatial Modeling, Extreme Value Theory, Streaming and Sampling Algorithms  
**Richard L. Smith (7)** (Mark L. Reed Distinguished Professor), Extreme Value Theory, Environmental Statistics, Spatial Statistics  
**Serhan Ziya (15)**, Stochastic Modeling, Healthcare Operations, Service Operations, Queueing Design and Control, Revenue Management

## Associate Professors

**Shankar Bhamidi (5)**, Probability, Random Networks, MCMC, Probabilistic Combinatorial Optimization

**Chuanshu Ji (4)**, Financial Econometrics, Computational Materials Science, Monte Carlo Methods  
**Shu Lu (9)**, Optimization, Equilibrium Problems  
**Marianna Olvera-Cravioto (20)**, Applied Probability, Random Graphs, Heavy-Tailed Large Deviations, Weighted Branching Processes, Stochastic Simulation  
**Gabor Pataki (12)**, Convex Programming, Integer Programming  
**Kai Zhang (16)**, Mathematical Statistics, High Dimensional Inference, Inference After Variable Selection, Large Deviation, Quantum Computing

## Assistant Professors

**Sayan Banerjee (18)**, Stochastic Analysis, Probabilistic Couplings, Interacting Particle Systems  
**Nicolas Fraiman (19)**, Random Structures, Combinatorial Statistics, Randomized Algorithms  
**Quoc Tran-Dinh (17)**, Numerical Optimization, Theory and Algorithms for Convex Optimization and Nonconvex Continuous Optimization

## Teaching Assistant Professors

**Robin Cunningham (21)**, Actuarial Models  
**Charles Dunn(22)**, Actuarial Models  
**Mario Giacomazzo (23)**, Statistics  
**Jeffrey McLean (24)**, Statistics

## Joint Professors

**Jason Fine** (Biostatistics) Nonparametrics  
**Joseph Ibrahim** (Alumni Distinguished Professor of Biostatistics) Bayesian Methods, Missing Data, Cancer Research  
**Michael Kosorok** (Biostatistics), Biostatistics, Empirical Processes, Semiparametric Inference, Machine Learning, Personalized Medicine, Clinical Trials, Dynamic Treatment Regimes  
**Jayashankar Swaminathan** (Benjamin Cone Research Professor, Kenan–Flagler Business School) Supply Chain, Stochastic Models

## Professors Emeriti

**George S. Fishman**  
**Douglas G. Kelly**  
**Malcolm Ross Leadbetter**  
**J. Scott Provan**  
**David S. Rubin**  
**Gordon D. Simons**  
**Walter L. Smith**  
**Shaler Stidham Jr.**  
**Jon W. Tolle**

## STOR

### Advanced Undergraduate and Graduate-level Courses

**STOR 415. Introduction to Optimization. 3 Credits.**  
 Linear, integer, nonlinear, and dynamic programming, classical optimization problems, network theory.  
**Requisites:** Prerequisite, MATH 547.  
**Grading status:** Letter grade.

**STOR 435. Introduction to Probability. 3 Credits.**

Introduction to mathematical theory of probability covering random variables; moments; binomial, Poisson, normal and related distributions; generating functions; sums and sequences of random variables; and statistical applications.

**Requisites:** Prerequisite, MATH 233.

**Gen Ed:** QI.

**Grading status:** Letter grade

**Same as:** MATH 535.

**STOR 445. Stochastic Modeling. 3 Credits.**

Introduction to Markov chains, Poisson process, continuous-time Markov chains, renewal theory. Applications to queueing systems, inventory, and reliability, with emphasis on systems modeling, design, and control.

**Requisites:** Prerequisite, BIOS 660 or STOR 435.

**Grading status:** Letter grade.

**STOR 455. Methods of Data Analysis. 3 Credits.**

Review of basic inference; two-sample comparisons; correlation; introduction to matrices; simple and multiple regression (including significance tests, diagnostics, variable selection); analysis of variance; use of statistical software.

**Requisites:** Prerequisite, STOR 155.

**Grading status:** Letter grade.

**STOR 465. Simulation for Analytics. 3 Credits.**

Introduces concepts of random number generation, random variate generation, and discrete event simulation of stochastic systems. Students perform simulation experiments using standard simulation software.

**Requisites:** Prerequisites, STOR 155 and 435.

**Grading status:** Letter grade.

**STOR 471. Long-Term Actuarial Models. 3 Credits.**

Probability models for long-term insurance and pension systems that involve future contingent payments and failure-time random variables. Introduction to survival distributions and measures of interest and annuities-certain.

**Requisites:** Prerequisite, STOR 435.

**Gen Ed:** QI.

**Grading status:** Letter grade.

**STOR 472. Short Term Actuarial Models. 3 Credits.**

Short term probability models for potential losses and their applications to both traditional insurance systems and conventional business decisions. Introduction to stochastic process models of solvency requirements.

**Requisites:** Prerequisite, STOR 435.

**Grading status:** Letter grade.

**STOR 493. Internship in Statistics and Operations Research. 3 Credits.**

Requires permission of the department. Statistics and analytics majors only. An opportunity to obtain credit for an internship related to statistics, operations research, or actuarial science. Pass/Fail only. Does not count toward the statistics and analytics major or minor.

**Gen Ed:** EE- Academic Internship.

**Repeat rules:** May be repeated for credit. 6 total credits. 2 total completions.

**Grading status:** Pass/Fail.

**STOR 496. Undergraduate Reading and Research in Statistics and Operations Research. 1-3 Credits.**

Permission of the director of undergraduate studies. This course is intended mainly for students working on honors projects. May be repeated for credit.

**Gen Ed:** EE- Mentored Research.

**Repeat rules:** May be repeated for credit; may be repeated in the same term for different topics; 6 total credits. 6 total completions.

**Grading status:** Letter grade.

**STOR 555. Mathematical Statistics. 3 Credits.**

Functions of random samples and their probability distributions, introductory theory of point and interval estimation and hypothesis testing, elementary decision theory.

**Requisites:** Prerequisite, STOR 435.

**Grading status:** Letter grade.

**STOR 556. Advanced Methods of Data Analysis. 3 Credits.**

Topics selected from: design of experiments, sample surveys, nonparametrics, time-series, multivariate analysis, contingency tables, logistic regression, and simulation. Use of statistical software packages.

**Requisites:** Prerequisites, STOR 435 and 455.

**Grading status:** Letter grade.

**STOR 565. Machine Learning. 3 Credits.**

Introduction to theory and methods of machine learning including classification; Bayes risk/rule, linear discriminant analysis, logistic regression, nearest neighbors, and support vector machines; clustering algorithms; overfitting, estimation error, cross validation.

**Requisites:** Prerequisites, STOR 215 or MATH 381, and STOR 435.

**Grading status:** Letter grade.

**STOR 612. Models in Operations Research. 3 Credits.**

Required preparation, calculus of several variables, linear or matrix algebra. Formulation, solution techniques, and sensitivity analysis for optimization problems which can be modeled as linear, integer, network flow, and dynamic programs. Use of software packages to solve linear, integer, and network problems.

**Grading status:** Letter grade.

**STOR 614. Linear Programming. 3 Credits.**

Required preparation, calculus of several variables, linear or matrix algebra. The theory of linear programming, computational methods for solving linear programs, and an introduction to nonlinear and integer programming. Basic optimality conditions, convexity, duality, sensitivity analysis, cutting planes, and Karush-Kuhn-Tucker conditions.

**Grading status:** Letter grade.

**STOR 634. Probability I. 3 Credits.**

Required preparation, advanced calculus. Lebesgue and abstract measure and integration, convergence theorems, differentiation. Radon-Nikodym theorem, product measures. Fubini theorems. Lp spaces.

**Grading status:** Letter grade.

**STOR 635. Probability II. 3 Credits.**

Foundations of probability. Basic classical theorems. Modes of probabilistic convergence. Central limit problem. Generating functions, characteristic functions. Conditional probability and expectation.

**Requisites:** Prerequisite, STOR 634; permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade

**Same as:** MATH 635.

**STOR 641. Stochastic Models in Operations Research I. 3 Credits.**

Review of probability, conditional probability, expectations, transforms, generating functions, special distributions, and functions of random variables. Introduction to stochastic processes. Discrete-time Markov chains. Transient and limiting behavior. First passage times.

**Requisites:** Prerequisite, STOR 435.

**Grading status:** Letter grade.

**STOR 642. Stochastic Models in Operations Research II. 3 Credits.**

Exponential distribution and Poisson process. Birth-death processes, continuous-time Markov chains. Transient and limiting behavior. Applications to elementary queueing theory. Renewal processes and regenerative processes.

**Requisites:** Prerequisite, STOR 641.

**Grading status:** Letter grade.

**STOR 654. Statistical Theory I. 3 Credits.**

Required preparation, two semesters of advanced calculus. Probability spaces. Random variables, distributions, expectation. Conditioning. Generating functions. Limit theorems: LLN, CLT, Slutsky, delta-method, big-O in probability. Inequalities. Distribution theory: normal, chi-squared, beta, gamma, Cauchy, other multivariate distributions. Distribution theory for linear models.

**Grading status:** Letter grade.

**STOR 655. Statistical Theory II. 3 Credits.**

Point estimation. Hypothesis testing and confidence sets. Contingency tables, nonparametric goodness-of-fit. Linear model optimality theory: BLUE, MVU, MLE. Multivariate tests. Introduction to decision theory and Bayesian inference.

**Requisites:** Prerequisite, STOR 654.

**Grading status:** Letter grade.

**STOR 664. Applied Statistics I. 3 Credits.**

Permission of the instructor. Basics of linear models: matrix formulation, least squares, tests. Computing environments: SAS, MATLAB, S+. Visualization: histograms, scatterplots, smoothing, QQ plots. Transformations: log, Box-Cox, etc. Diagnostics and model selection.

**Grading status:** Letter grade.

**STOR 665. Applied Statistics II. 3 Credits.**

ANOVA (including nested and crossed models, multiple comparisons). GLM basics: exponential families, link functions, likelihood, quasi-likelihood, conditional likelihood. Numerical analysis: numerical linear algebra, optimization; GLM diagnostics. Simulation: transformation, rejection, Gibbs sampler.

**Requisites:** Prerequisite, STOR 664; permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade.

**STOR 672. Simulation Modeling and Analysis. 3 Credits.**

Introduces students to modeling, programming, and statistical analysis applicable to computer simulations. Emphasizes statistical analysis of simulation output for decision-making. Focuses on discrete-event simulations and discusses other simulation methodologies such as Monte Carlo and agent-based simulations. Students model, program, and run simulations using specialized software. Familiarity with computer programming recommended.

**Requisites:** Prerequisites, STOR 555 and 641.

**Grading status:** Letter grade

**Same as:** COMP 672.

**STOR 691H. Honors in Statistics and Analytics. 3 Credits.**

Permission of the department. Majors only. Individual reading, study, or project supervised by a faculty member.

**Gen Ed:** EE- Mentored Research.

**Grading status:** Letter grade.

**STOR 692H. Honors in Statistics and Analytics. 3 Credits.**

Permission of the department. Majors only. Individual reading, study, or project supervised by a faculty member.

**Gen Ed:** EE- Mentored Research.

**Grading status:** Letter grade.

**Graduate-level Courses****STOR 701. Statistics and Operations Research Colloquium. 1 Credit.**

This seminar course is intended to give Ph.D. students exposure to cutting edge research topics in statistics and operations research and assist them in their choice of a dissertation topic. The course also provides a forum for students to meet and learn from major researchers in the field.

**Repeat rules:** May be repeated for credit. 10 total credits. 10 total completions.

**Grading status:** Letter grade.

**STOR 705. Operations Research Practice. 3 Credits.**

Gives students an opportunity to work on an actual operations research project from start to finish under the supervision of a faculty member. Intended exclusively for operations research students.

**Requisites:** Prerequisites, STOR 614, 641, and 672; Permission of the instructor for students lacking the prerequisites.

**Grading status:** Letter grade.

**STOR 712. Mathematical Programming I. 3 Credits.**

Advanced topics from mathematical programming such as geometry of optimization, parametric analysis, finiteness and convergence proofs, and techniques for large-scale and specially structured problems.

**Requisites:** Prerequisites, MATH 661 and STOR 614; permission of the instructor for students lacking the prerequisites.

**Grading status:** Letter grade.

**STOR 713. Mathematical Programming II. 3 Credits.**

Advanced theory for nonlinear optimization. Algorithms for unconstrained and constrained problems.

**Requisites:** Prerequisite, STOR 712; permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade.

**STOR 722. Integer Programming. 3 Credits.**

Techniques for formulating and solving discrete valued and combinatorial optimization problems. Topics include enumerative and cutting plane methods, Lagrangian relaxation, Benders' decomposition, knapsack problems, and matching and covering problems.

**Requisites:** Prerequisite, STOR 614; permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade.

**STOR 724. Networks. 3 Credits.**

Network flow problems and solution algorithms; maximum flow, shortest route, assignment, and minimum cost flow problems; Hungarian and out-of-kilter algorithms; combinatorial and scheduling applications.

**Requisites:** Prerequisite, STOR 614; permission of the instructor for students lacking the prerequisites.

**Grading status:** Letter grade.

**STOR 734. Stochastic Processes. 3 Credits.**

Discrete and continuous parameter Markov chains, Brownian motion, stationary processes.

**Requisites:** Prerequisite, STOR 435.

**Grading status:** Letter grade.

**STOR 743. Stochastic Models in Operations Research III. 3 Credits.**

Intermediate queueing theory, queueing networks. Reliability. Diffusion processes and applications. Markov decision processes (stochastic dynamic programming): finite horizon, infinite horizon, discounted and average-cost criteria.

**Requisites:** Prerequisite, STOR 642.

**Grading status:** Letter grade.

**STOR 744. Queueing Networks. 3 Credits.**

Jackson networks; open and closed. Reversibility and quasi-reversibility. Product form networks. Nonproduct form networks. Approximations. Applications to computer performance evaluations and telecommunication networks.

**Requisites:** Prerequisite, STOR 642; permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade.

**STOR 754. Time Series and Multivariate Analysis. 3 Credits.**

Introduction to time series: exploratory analysis, time-domain analysis and ARMA models, Fourier analysis, state space analysis. Introduction to multivariate analysis: principal components, canonical correlation, classification and clustering, dimension reduction.

**Requisites:** Prerequisites, STOR 435 and 555.

**Grading status:** Letter grade.

**STOR 755. Estimation, Hypothesis Testing, and Statistical Decision. 3 Credits.**

Bayes procedures for estimation and testing. Minimax procedures. Unbiased estimators. Unbiased tests and similar tests. Invariant procedures. Sufficient statistics. Confidence sets. Large sample theory. Statistical decision theory.

**Requisites:** Prerequisites, STOR 635 and 655.

**Grading status:** Letter grade.

**STOR 756. Design and Robustness. 3 Credits.**

Introduction to experimental design, including classical designs, industrial designs, optimality, and sequential designs. Introduction to robust statistical methods; bootstrap, cross-validation, and resampling.

**Requisites:** Prerequisite, STOR 555.

**Grading status:** Letter grade.

**STOR 757. Bayesian Statistics and Generalized Linear Models. 3 Credits.**

Bayes factors, empirical Bayes theory, applications of generalized linear models.

**Requisites:** Prerequisite, STOR 555.

**Grading status:** Letter grade.

**STOR 763. Statistical Quality Improvement. 3 Credits.**

Methods for quality improvement through process control, graphical methods, designed experimentation. Shewhart charts, cusum schemes, methods for autocorrelated multivariate process data, process capability analysis, factorial and response surface designs, attribute sampling.

**Requisites:** Prerequisites, STOR 655 and 664.

**Grading status:** Letter grade.

**STOR 765. Statistical Consulting. 1.5 Credit.**

Application of statistics to real problems presented by researchers from the University and local companies and institutes. (Taught over two semesters for a total of 3 credits.)

**Repeat rules:** May be repeated for credit. 3 total credits. 2 total completions.

**Grading status:** Letter grade.

**STOR 767. Advanced Statistical Machine Learning. 3 Credits.**

This is a graduate course on statistical machine learning.

**Requisites:** Prerequisites, STOR 654,655, 664, 665 and permission of the instructor.

**Grading status:** Letter grade.

**STOR 772. Introduction to Inventory Theory. 3 Credits.**

Permission of the instructor. Introduction to the techniques of constructing and analyzing mathematical models of inventory systems.

**Grading status:** Letter grade.

**STOR 790. Operations Research and Systems Analysis Student Seminar. 1 Credit.**

Survey of literature in operations research and systems analysis.

**Grading status:** Letter grade.

**STOR 822. Topics in Discrete Optimization. 3 Credits.**

Topics may include polynomial algorithms, computational complexity, matching and matroid problems, and the traveling salesman problem.

**Requisites:** Prerequisite, STOR 712; Permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade

**Same as:** COMP 822.

**STOR 824. Computational Methods in Mathematical Programming. 3 Credits.**

Advanced topics such as interior point methods, parallel algorithms, branch and cut methods, and subgradient optimization.

**Requisites:** Prerequisite, STOR 712; Permission of the instructor for students lacking the prerequisite.

**Grading status:** Letter grade.

**STOR 831. Advanced Probability. 3 Credits.**

Advanced theoretic course, covering topics selected from weak convergence theory, central limit theorems, laws of large numbers, stable laws, infinitely divisible laws, random walks, martingales.

**Requisites:** Prerequisites, STOR 634 and 635.

**Repeat rules:** May be repeated for credit. 9 total credits. 3 total completions.

**Grading status:** Letter grade.

**STOR 832. Stochastic Processes. 3 Credits.**

Advanced theoretic course including topics selected from foundations of stochastic processes, renewal processes, Markov processes, martingales, point processes.

**Requisites:** Prerequisites, STOR 634 and 635.

**Grading status:** Letter grade.

**STOR 833. Time Series Analysis. 3 Credits.**

Analysis of time series data by means of particular models such as autoregressive and moving average schemes. Spectral theory for stationary processes and associated methods for inference. Stationarity testing.

**Requisites:** Prerequisites, STOR 634 and 635.

**Grading status:** Letter grade.

**STOR 834. Extreme Value Theory. 3 Credits.**

This course covers both mathematical theory and statistical methodology concerned with extreme values in sequences of random variables. IID theory: the three types of extreme value distributions, statistical methods by block maxima and threshold exceedances. Extensions to dependent stochastic sequences: the extremal index and related concepts. Multivariate and spatial extremes, max-stable process. Applications in: engineering and strength of materials; finance and insurance; environment and climate.

**Requisites:** Prerequisites, STOR 635 and 654.

**Grading status:** Letter grade.

**STOR 835. Point Processes. 3 Credits.**

Random measures and point processes on general spaces, Poisson and related processes, regularity, compounding. Point processes on the real line stationarity, Palm distributions, Palm-Khintchine formulae. Convergence and related topics.

**Requisites:** Prerequisite, STOR 635.

**Grading status:** Letter grade.

**STOR 836. Stochastic Analysis. 3 Credits.**

Brownian motion, semimartingale theory, stochastic integrals, stochastic differential equations, diffusions, Girsanov's theorem, connections with elliptic PDE, Feynman-Kac formula. Applications: mathematical finance, stochastic networks, biological modeling.

**Requisites:** Prerequisites, STOR 634 and 635.

**Grading status:** Letter grade.

**STOR 842. Control of Stochastic Systems in Operations Research. 3 Credits.**

Review of Markov decision processes. Monotone control policies. Algorithms. Examples: control of admission, service, routing and scheduling in queues and networks of queues. Applications: manufacturing systems, computer/communication systems.

**Requisites:** Prerequisites, STOR 641 and 642.

**Grading status:** Letter grade.

**STOR 851. Sequential Analysis. 3 Credits.**

Hypothesis testing and estimation when sample size depends on the observations. Sequential probability ratio tests. Sequential design of experiments. Optimal stopping. Stochastic approximation.

**Requisites:** Prerequisites, STOR 635 and 655.

**Grading status:** Letter grade.

**STOR 852. Nonparametric Inference: Rank-Based Methods. 3 Credits.**

Estimation and testing when the functional form of the population distribution is unknown. Rank, sign, and permutation tests. Optimum nonparametric tests and estimators including simple multivariate problems.

**Requisites:** Prerequisites, STOR 635 and 655.

**Grading status:** Letter grade.

**STOR 853. Nonparametric Inference: Smoothing Methods. 3 Credits.**

Density and regression estimation when no parametric model is assumed. Kernel, spline, and orthogonal series methods. Emphasis on analysis of the smoothing problem and data based smoothing parameter selectors.

**Requisites:** Prerequisites, STOR 635 and 655.

**Grading status:** Letter grade.

**STOR 854. Statistical Large Sample Theory. 3 Credits.**

Asymptotically efficient estimators; maximum likelihood estimators. Asymptotically optimal tests; likelihood ratio tests.

**Requisites:** Prerequisites, STOR 635 and 655.

**Grading status:** Letter grade.

**STOR 855. Subsampling Techniques. 3 Credits.**

Basic subsampling concepts: replicates, empirical c.d.f., U-statistics. Subsampling for i.i.d. data: jackknife, typical-values, bootstrap. Subsampling for dependent or nonidentically distributed data: blockwise and other methods.

**Requisites:** Prerequisite, STOR 655.

**Grading status:** Letter grade.

**STOR 856. Multivariate Analysis. 3 Credits.**

Required preparation, matrix theory, multivariate normal distributions. Related distributions. Tests and confidence intervals. Multivariate analysis of variance, covariance and regression. Association between subsets of a multivariate normal set. Theory of discriminant, canonical, and factor analysis.

**Requisites:** Prerequisite, STOR 655.

**Grading status:** Letter grade.

**STOR 857. Nonparametric Multivariate Analysis. 3 Credits.**

Nonparametric MANOVA. Large sample properties of the tests and estimates. Robust procedures in general linear models, including the growth curves. Nonparametric classification problems.

**Requisites:** Prerequisite, STOR 852.

**Grading status:** Letter grade.

**STOR 881. Object Oriented Data Analysis. 1-3 Credits.**

Object Oriented Data Analysis (OODA) is the statistical analysis of populations of complex objects. Examples include data sets where the data points could be curves, images, shapes, movies, or tree structured objects.

**Grading status:** Letter grade.

**STOR 890. Special Problems. 1-3 Credits.**

Permission of the instructor.

**Repeat rules:** May be repeated for credit.

**Grading status:** Letter grade.

**STOR 891. Special Problems. 1-3 Credits.**

Permission of the instructor.

**Repeat rules:** May be repeated for credit; may be repeated in the same term for different topics.

**Grading status:** Letter grade.

**STOR 892. Special Topics in Operations Research and Systems Analysis. 1-3 Credits.**

Permission of the instructor.

**Repeat rules:** May be repeated for credit.

**Grading status:** Letter grade.

**STOR 893. Special Topics. 1-3 Credits.**

Advance topics in current research in statistics and operations research.

**Repeat rules:** May be repeated for credit.

**Grading status:** Letter grade.

**STOR 894. Special Topics at SAMSI. 3 Credits.**

Advanced topics in current research in statistics and operations research. This course is held at SAMSI.

**Repeat rules:** May be repeated for credit. 6 total credits. 2 total completions.

**Grading status:** Letter grade.

**STOR 910. Directed Reading in Operations Research and Systems Analysis. 1-21 Credits.**

Permission of the instructor.

**Grading status:** Letter grade.

**STOR 930. Advanced Research. 1-3 Credits.**

Permission of the instructor.

**Grading status:** Letter grade.

**STOR 940. Seminar in Theoretical Statistics. 1-3 Credits.**

Prerequisite, STOR 655.

**Repeat rules:** May be repeated for credit.

**Grading status:** Letter grade.

**STOR 950. Advanced Research. 0.5-21 Credits.**

Permission of the instructor.

**Grading status:** Letter grade.

**STOR 960. Seminar in Theoretical Statistics. 0.5-21 Credits.**

Prerequisite, STOR 655.

**Grading status:** Letter grade.

**STOR 970. Practicum. 1-3 Credits.**

Students work with other organizations (Industrial/Governmental) to gain practical experience in Statistics and Operations Research.

**Repeat rules:** May be repeated for credit.

**Grading status:** Letter grade.

**STOR 992. Master's (Non-Thesis). 3 Credits.**

Permission of instructor.

**Repeat rules:** May be repeated for credit.

**STOR 994. Doctoral Research and Dissertation. 3 Credits.**

Permission of instructor.

**Repeat rules:** May be repeated for credit.