DEPARTMENT OF STATISTICS AND OPERATIONS RESEARCH (GRAD)

Contact Information
Department of Statistics and Operations Research
http://stat-or.unc.edu

Amarjit Budhiraja, Chair

The department offers the master of science (M.S.) and doctor of philosophy (Ph.D.) in statistics and operations research (STOR). Each degree encompasses three programs: statistics (STAT), operations research (OR), and interdisciplinary statistics and operations research (INSTORE).

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 four to 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.

The M.S. degree in STOR prepares students for jobs in industry and government, and for further graduate study. The philosophy of the M.S. degree is to train students in the basic theory and applications of statistics and/or operations research. Completion of the M.S. degree typically requires two years of full-time graduate study.

Further information on the graduate degree programs can be obtained from the department’s home page (http://www.stat-or.unc.edu). Information about the OR, STAT, and INSTORE programs may also be obtained from the admissions chair of the individual programs, CB# 3260, Hanes Hall, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599.

Application forms (http://gradschool.unc.edu/admissions) for admission and/or financial aid are available through the Web site of The Graduate School. Students can indicate on this application form whether they intend to pursue the degree program in OR, STAT, or INSTORE. Applicants are required to submit scores for both the Aptitude and Advanced Mathematics portions of the Graduate Record Examination (GRE) in support of their application, and a supplementary sheet providing brief course descriptions (including textbook title where applicable) of previous undergraduate and graduate courses in mathematics, probability, and statistics.

Graduate 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.

The operations research faculty consists of a resident faculty and an interdisciplinary faculty, with programs of study that offer considerable opportunity for the pursuit of individual student interests. Specialization is possible in deterministic optimization theory (such as nonlinear and integer programming), in stochastic processes and applied probability (such as queueing theory and simulation), or in an approved area of application (such as management science).

The M.S. program is intended for the student who is preparing for a career in industry, government, or consulting. The Ph.D. program emphasizes theoretical depth and is tailored primarily for the student who is preparing for a career in teaching and/or research. Each program includes study of the mathematical foundations of operations research. In either case, the specific program of study for each student is determined to a large extent on an individual basis through consultations with a faculty advisor to obtain a balance between application and theory. Although it is possible for the well-prepared student to complete the M.S. requirements in three semesters, it more typically requires four semesters. The Ph.D. program, including the dissertation, generally requires four or five years beyond the bachelor’s degree. The department offers a minor for Ph.D. students in other departments. The department also offers a course sequence that enables qualified UNC-Chapel Hill undergraduates in the mathematical decision sciences B.S. degree program to fulfill the requirements for the M.S. degree in operations research in one additional academic year (beyond the four years required for the undergraduate degree).

Requirements for Admission to Graduate Study in Operations Research

Applicants must have demonstrated a high level of scholastic ability in their undergraduate studies and must satisfy the entrance requirements of The Graduate School. No restrictions are placed on the undergraduate major for admission to the program. However, to be prepared adequately for study in operations research, an applicant should have a good mathematical background, including courses in advanced calculus, linear or matrix algebra, probability and statistics, and the knowledge of a computer language. A student admitted with a deficiency in one or more of these topics 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.

Graduate Program in Statistics

The statistics program offers graduate training leading to the master of science (M.S.) and doctor of philosophy (Ph.D.) degrees. The M.S. degree may be included in the doctoral program. Applicants for financial aid are considered for assistantships within the department, as well
as for various fellowships and limited service awards provided on a competitive university-wide basis by The Graduate School. Assistants perform academically related duties, such as teaching, grading, and leading tutorials. Other awards include merit assistantships, University graduate and alumni fellowships, Pogue fellowships, and Morehead fellowships. Assistantships and fellowships generally include a stipend for the academic year as well as tuition.

Application for admission and financial aid may be made simultaneously simply by indicating on the admission application form a desire to be considered for financial aid.

More detailed information about the statistics program is available on the department’s home page (http://www.stat-or.unc.edu). Specific inquiries should be addressed to the Director of Graduate Admissions, Statistics Program, CB# 3260, The University of North Carolina at Chapel Hill, Chapel Hill, N.C. 27599-3260.

Degree Requirements for Operations Research

Candidates for degrees in operations research must meet the general requirements of The Graduate School. Course selections for a degree in operations research are taken from the department's offerings and from the regular offerings of related departments, including the Departments of Biostatistics, City and Regional Planning, Computer Science, Epidemiology, Economics, Health Policy and Management, Mathematics, and Psychology and Neuroscience, as well as the School of Information and Library Science, the Kenan–Flagler Business School at UNC–Chapel Hill, and the Fuqua School of Business at Duke University.

For more details, see the department's Web site (http://stat-or.unc.edu/programs) and click on "Operations Research."

Degree Requirements for Statistics

M.S. 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. To meet the course requirements, students typically take 15 three-credit courses. Most courses are selected from among those offered by the statistics program, but approved courses from outside the program can also be counted toward the 45-credit minimum.

The Ph.D. curriculum in statistics places strong emphasis on the mathematical foundations of statistics and probability. A sound mathematical preparation is thus an essential prerequisite for admission to the program. An applicant's mathematical background should include a one-year course in real analysis, at least one semester of matrix algebra, and calculus-based courses in probability and statistics.

For more details, see 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.

INSTORE Program

A Ph.D. and M.S. 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 or who want to develop significant expertise in the applications of statistics and operations research to some outside area such as genetics, finance, social science, or environmental science. The INSTORE program allows flexibility for adaptively combining statistics, operations research, and external fields of application. However, there are specific tracks that contain suggested sequences of courses allowing students to focus on certain areas of study. For example, there is a track in applied statistics and optimization, a track in computational finance, and a track in business analytics; additional tracks are planned in econometrics and in bioinformatics. A mechanism also exists for students to propose their own track, subject to approval by the department's faculty. For detailed descriptions of the content and requirements of the INSTORE program (http://stat-or.unc.edu/programs), go to the Web site and click on "Interdisciplinary Statistics and Operations Research."

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

Amarjit Budhiraja (2), Probability, Stochastic Analysis, Large Deviations, Stochastic Control
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, Asymptotics, Visualization, Smoothing, Biomedical Collaborations
Andrew Nobel (11), Machine Learning, Data Mining, Computational Genomics
Vladas Pipiras (13), Time Series and Spatial Modeling, Extreme Value Theory, Streaming and Sampling Algorithms
**Associate Professors**

Pranab Kumar Sen (21) (Cary C. Boshamer Professor), Statistical Inference, Multivariate Analysis, Sequential Analysis, Clinical Trials, Environmetrics, Bioinformatics.

Richard L. Smith (22) (Mark L. Reed Distinguished Professor and Director), Statistical and Applied Mathematical Sciences Institute, Extreme Value Theory, Environmental Statistics, Spatial Statistics

Serhan Ziya (15), Stochastic Models, Revenue Management, Service Operations

Nilay Argon (1), Stochastic Models, Queueing Design and Control, Healthcare Operations, Simulation

Shankar Bhamidi (5), Network Models and Applications, Probabilistic Combinatorial Optimization

Chuang Shu Ji (4), Financial Econometrics, Computational Materials Science, Monte Carlo Methods

Shu Lu (9), Optimization, Variational Inequalities

Gabor Pataki (12), Convex Programming, Convex Analysis, Integer Programming

**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

Kai Zhang (16), Mathematical Statistics, High Dimensional Inference, Inference after Variable Selection, Large Deviation, Quantum Computing

**Lecturers**

Robin Cunningham, Actuarial Models

Charles Dunn, Actuarial Models

**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**

Charles R. Baker

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

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**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. Statistical Methods I. 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, BIOS 660 or MATH 535.

**Gen Ed:** QI.

**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.

**Gen Ed:** QI.

**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, BIOS 470.

**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.

**Gen Ed:** QI.

**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. Measure and Integration. 3 Credits.
Grading status: Letter grade.

STOR 635. Probability. 3 Credits.
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.
Requisites: Prerequisite, STOR 435.
Grading status: Letter grade.

STOR 642. Stochastic Models in Operations Research II. 3 Credits.
Requisites: Prerequisite, STOR 641.
Grading status: Letter grade.

STOR 654. Statistical Theory I. 3 Credits.
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.
Grading status: Letter grade.

STOR 665. Applied Statistics II. 3 Credits.
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.

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.

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.

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.

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.

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.

STOR 734. Stochastic Processes. 3 Credits.
Discrete and continuous parameter Markov chains, Brownian motion, stationary processes.
Requisites: Prerequisite, STOR 435.

STOR 744. Queueing Networks. 3 Credits.
Requisites: Prerequisite, STOR 642.

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.

STOR 755. Estimation, Hypothesis Testing, and Statistical Decision. 3 Credits.
Requisites: Prerequisites, STOR 635 and 655.

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.

STOR 757. Bayesian Statistics and Generalized Linear Models. 3 Credits.
Bayes factors, empirical Bayes theory, applications of generalized linear models.
Requisites: Prerequisite, STOR 555.

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.

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.
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.

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.

STOR 790. Operations Research and Systems Analysis Student Seminar. 1 Credit.
Survey of literature in operations research and systems analysis.

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.
**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.

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.

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.

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.

STOR 834. Extreme Value Theory. 3 Credits.
Classical asymptotic distributional theory for maxima and order statistics from i.i.d. sequences, including extremal types theorem, domains of attraction, Poisson properties of high level exceedances. Stationary stochastic sequences and continuous time processes.
**Requisites:** Prerequisites, STOR 635 and 654.

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.

STOR 836. Stochastic Analysis. 3 Credits.
**Requisites:** Prerequisites, STOR 634 and 635.

STOR 842. Control of Stochastic Systems in Operations Research. 3 Credits.
**Requisites:** Prerequisites, STOR 641 and 642.

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.

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.

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.

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.

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.

STOR 856. Multivariate Analysis. 3 Credits.
**Requisites:** Prerequisite, STOR 655.

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.

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.

STOR 890. Special Problems. 1-3 Credits.
Permission of the instructor.
**Repeat rules:** May be repeated for credit.

STOR 891. Special Problems. 1-3 Credits.
Permission of the instructor.
**Repeat rules:** May be repeated for credit.
STOR 892. Special Topics in Operations Research and Systems Analysis. 1-3 Credits.
Permission of the instructor.
Repeat rules: May be repeated for credit.

STOR 893. Special Topics. 1-3 Credits.
Advance topics in current research in statistics and operations research.
Repeat rules: May be repeated for credit.

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.

STOR 910. Directed Reading in Operations Research and Systems Analysis. 1-21 Credits.
Permission of the instructor.

STOR 930. Advanced Research. 1-3 Credits.
Permission of the instructor.

STOR 940. Seminar in Theoretical Statistics. 1-3 Credits.
Requisites: Prerequisite, STOR 655.
Repeat rules: May be repeated for credit.

STOR 950. Advanced Research. 0.5-21 Credits.
Permission of the instructor.

STOR 960. Seminar in Theoretical Statistics. 0.5-21 Credits.
Requisites: Prerequisite, STOR 655.

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.

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.