GRADUATE STUDIES IN
APPLIED MATHEMATICS

AIR FORCE INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MATHEMATICS AND STATISTICS
BROCHURE
2019-2020

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT
Wright-Patterson Air Force Base, Ohio
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This statement of regulations and requirements complements the Institute's regulations and requirements which are contained in the AFIT Graduate Catalog as well as appropriate AFIT Instructions and Graduate School of Engineering and Management Operating Instructions.
The Institute and the Department

The Air Force Institute of Technology (AFIT) is the graduate school of the United States Air Force and the premier institution for defense-related graduate education in science, engineering, advanced technology, and management for the Department of Defense. Established as the Air School of Application in 1919, it took its present name in 1947 when the Air Force became a separate service. The first graduate degrees were granted in 1956 and the first Ph.D. degrees were conferred in 1969. Since that time more than twelve thousand graduate degrees have been conferred by AFIT, including over 300 doctorates. The Institute has a total enrollment of approximately 800 resident graduate students, the bulk of whom are U.S. Air Force officers.

AFIT is located on Wright-Patterson Air Force Base near Dayton, Ohio, the birth place of controlled powered flight and home to the Air Force Research Laboratory and five of its directorates. The Institute is authorized to enroll, in addition to Air Force officers and enlisted personnel, federal civilian employees and a limited number of defense industry employees. (U.S. citizenship is required.) Because of this AFIT has seen a significant increase in the number of civilians attending in recent years. While AFIT’s primary goal is to provide graduate education for Air Force officers, there is a strong collegial bond between military and civilian students providing a unique and memorable graduate education experience.

The Department of Mathematics and Statistics is one of six departments in the Graduate School of Engineering and Management and teaches graduate courses for practically every program in the Institute. The department faculty consists of approximately half civilian and half military, all actively engaged in research on problems in applied mathematics.

Research Assistantships are available on a limited basis for qualified students. Interested students are encouraged to contact the department for further information.

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Graduate Program in Applied Mathematics

The Department of Mathematics and Statistics offers graduate programs leading to the degrees Master of Science (M.S.) and Doctor of Philosophy (Ph.D.). Specialization can be in any of the areas of analysis or statistics, including numerical analysis.

Master of Science Program (M.S.) The aim of the master's degree program is to provide a balanced foundational education in mathematical and statistical analysis, an understanding of appropriate applications of the theory, and some depth in an area of specialization. The program is designed for students who have completed an undergraduate major in mathematics or statistics. However, students with a strong record in mathematics from any other area of study will usually find their preparation to be adequate. The department believes that the applied nature of the program is enhanced by interaction with at least one other department in the Graduate School of Engineering and Management. Therefore, an out-of-department sequence taken from another department is required and serves to help the future applied mathematician gain an appreciation for communicating with other scientists and engineers. In addition, the thesis project is invariably linked to an Air Force or defense department organization, further enhancing the student's appreciation for and experience in working with the nonmathematician.

Doctor of Philosophy Program (Ph.D.) The aim of the doctoral program is to provide comprehensive knowledge of existing theory and how it applies to problems in science and engineering along with the opportunity to extend the world's knowledge significantly beyond those bounds. Being an applied program, particular emphasis is placed on educating students to recognize the relevance of analytical and numerical methods to the solution of specific problems and to enable them to develop new methods when they are needed. The education aims to produce an applied mathematician with the ability to develop new theoretical results and apply them as the need arises. Central to this goal is the research part of the program. Both the ability to conduct the research successfully and to report it in a coherent and fully documented dissertation is essential to the program. The program is kept sufficiently flexible, however, to permit students to develop their own specific interests.
Master of Science Program

The Master of Science (M.S.) program usually takes 18 months (six quarters) to complete. Entering students are assigned a faculty member as Academic Advisor to assist in setting up a tentative education plan merging the student's interests with program requirements. The student will eventually select a thesis advisor, with the approval of the Department Head, who will guide the student’s thesis research. An oral defense of the thesis in the presence of the advisor and at least two faculty readers is also required. Although the readers’ assessment of the thesis work is important, the thesis advisor is solely responsible for assigning a letter grade to the thesis.

Program Outcomes: Graduates of the program will be able to: (1) Understand an applied problem well enough to give a mathematical formulation of it; (2) Analyze a problem rigorously and propose credible solutions; (3) Communicate mathematical concepts effectively by written and oral means.

Summary of Master of Science Degree Requirements

Admission Requirements
- Bachelor's degree in mathematics or in any other academic discipline if it includes a strong record in mathematics.
- Undergraduate GPA of 3.0 (4.0 system).
- Graduate Record Examination (GRE) scores of 153 (verbal) and 148 (quantitative).
- United States citizen.

Minimum Requirements for M.S. degree
Complete an approved education plan containing at least 48 hrs with a GPA of 3.0 (4 pt system) or better which includes the following:
- MATH 600 (Mathematical Analysis) or MATH 602 (Modern Applied Mathematics I).
- MATH 601 (Complex Analysis).
- STAT 601 (Theory of Probability).
- STAT 602 (Mathematical Statistics).
- Out-of-department sequence (8 hrs).
- Three courses (12 hrs) in area of specialization.
- Thesis (12 hrs) and successful oral defense.
Doctor of Philosophy Program

The doctoral program normally takes 36 months (12 quarters) beyond the master’s degree to complete. The course work takes a minimum of one year of full-time study, leaving the remaining time to conduct the research, write the dissertation, and make a successful public oral defense of the work.

Entering students seeking a Doctor of Philosophy (Ph.D.) degree meet with the Department Head to discuss his/her academic interests, expectations, and goals. Based on this discussion, the Department Head will assign a pro tem advisor with interests similar to the student's. The student, working closely with the pro tem advisor, then sets up a tentative education plan for his/her doctoral program being careful to fulfill the general requirements of the doctoral program (see next page). The pro tem advisor continues to advise the student until the student has decided on his/her preference for a research advisor. The research advisor and the student's research committee are appointed by the Department Head with the full participation of the student.

Program Examinations

The doctoral program requires the student to pass, other than the final oral defense of the dissertation, an examination over his/her major area of study. The examination occurs in two parts neither of which can be waived. The first part is a written examination over the subject area. Some time later the student is given an oral examination over the course material and research prospectus. The research prospectus is the student's written documentation of the problem to be researched for the dissertation and its relevant history. The prospectus includes, at a minimum, a statement of the problem, its importance to the scientific community, a background study of similar work that has been done, and the student's plan for attacking the problem. By passing the student on the oral part of the major examination, the research committee is, in essence, telling the student that he/she knows the subject area adequately, has a reasonable problem to study for the doctoral degree, and has a credible plan for attacking the problem.
Summary of the Ph. D. Program Requirements

Specializations Available
- Analysis
- Statistics
- Numerical Analysis

Admission Requirements
- Master's degree in mathematics, statistics, or any other academic discipline if it includes a strong graduate record in mathematics or statistics
- Overall graduate GPA of 3.5 (4.0 system)
- Graduate Record Examination (GRE) scores of 156 (verbal) and 151 (quantitative)
- United States citizen

Minimum Requirements for Ph.D. degree
Complete an approved program of study under the direction of a research committee appointed by the Department Head in consultation with the student. The program must include the following:
- Three quarters of full-time study in residence during any contiguous four-quarter period
- 36 hrs of courses beyond the master's degree to include at least 24 hrs in the major area of study and at least 8 hrs in an area taken outside the Department of Mathematics and Statistics
- 48 hrs of supervised research
- Pass the specialty exam in a timely manner
- Be admitted to candidacy for the degree at least one year prior to graduation
- Dissertation
- Successfully present a public, oral defense of the dissertation

Doctoral Committee Policy Letter
The Doctoral Committee establishes policy for the doctoral program, and therefore all students in the program should become thoroughly familiar with the committee’s Policy Letter. It is available on the AFIT intranet at http://org.eis.afit.edu/dept/en/DoctoralCommitteePolicyLetter/Doctoral%20Committee%20Policy%20Letter.pdf.
Fully Funded Air Force Students

Air Force officers assigned to attend AFIT in order to obtain an advanced degree will also be required to qualify for a particular Air Force Academic Specialty Code (ASC). In some cases, this will require them to take additional courses. In the doctoral program, additional courses will normally not be needed. However, the master's program will usually require additional work. Among the available options and their academic specialty codes are:

- Analysis - 6BYY
- Information and Communication Theory – 6EKY
- Numerical Analysis - 6GYY
- Mathematics – 6YYY
- Reliability & Maintainability - 6IRY
- Statistics – 6IYY

Since these academic specialties sometimes require additional courses, we provide details here of the specific requirements for each of these options.

**Common to all Master of Science options in Applied Mathematics:**

- **Core:** STAT 601, STAT 602, MATH 601, and either MATH 600 or MATH 602.
- **Specialty sequence (12 hrs)**
- **Out-of-department sequence (8 hrs)**
- **Thesis (12 hrs)**

The student may then choose courses in his/her master's degree specialty sequence as follows:

- **Analysis - 6BYY:** Three MATH courses numbered 600 or above.

- **Information and Communication Theory- 6EKY:** Three courses from MATH 621, MATH 631, MATH 633, MATH 672 and MATH 705

- **Statistics - 6IRY:** STAT 687, STAT 694, STAT 697 (Reliability & Maintainability specialty)

- **Statistics - 6IYY:** Three STAT courses numbered 600 or above.

- **Numerical Analysis - 6GYY:** MATH 672, MATH 674, MATH 676.

- **Mathematics – 6YYY:** Three MATH and/or STAT courses numbered 600 or above.
Faculty

**Akers, Benjamin F.**, Associate Professor of Mathematics  
BS, MA, PhD (University of Wisconsin – Madison)  
*Nonlinear Waves, Numerical Analysis, Fluid Mechanics*

**Anderson, Timothy S (‘Shawn’), Maj**, Assistant Professor of Statistics  
BS, MS, PhD (Air Force Institute of Technology)  
*Computational Statistics, Uncertainty Quantification, Analytics*

**Baker, William P.**, Associate Professor of Mathematics  
BA, MA, PhD (Northwestern University)  
*Asymptotic and Perturbation Methods, Wave Propagation, Scattering Theory*

**Benrose, Travis J.**, Maj, Assistant Professor of Mathematics  
BS, MS, PhD (University of Missouri-Columbia)  
*Applied Harmonic Analysis, Frame Theory*

**Brooks, Eric L.**, Maj, Assistant Professor of Statistics  
BS, MS, PhD (Air Force Institute of Technology)  
*Statistical Machine Learning, Big Data*

**Bulutoglu, Dursun A.**, Associate Professor of Statistics  
BS, MA, PhD (University of California, Berkeley)  
*Design of Experiments, Combinatorial Optimization, Symmetric Integer Programming*

**Fickus, Matthew C.**, Professor of Mathematics  
BS, MS, PhD (University of Maryland, College Park)  
*Applied Harmonic Analysis, Frame Theory, Compressed Sensing*

**Geyer, Andrew J.**, Lt Col, Deputy Department Head and Assistant Professor of Statistics  
BS, MS, PhD (Air Force Institute of Technology)  
*Design of Experiments, Combinatorial Optimization*

**Hartlage, R. Benjamin**, Lt Col, Assistant Professor of Statistics  
BS, MS, MS, PhD (Air Force Institute of Technology)  
*Large-Scale Mathematical Programming, Network Optimization*

**Jordan, Jeremy D.**, Lt Col, Assistant Professor of Statistics  
BA, MS, PhD (Air Force Institute of Technology)  
*Operations Research, Analytics, Network Optimization*

**Lair, Alan V.**, Department Head and Professor of Mathematics  
BA, MS, PhD (Texas Tech University)  
*Partial Differential Equations, Functional Analysis*
Liu, Tony, Capt, Assistant Professor of Mathematics
BA, MS, PhD (Arizona State University)
Approximation Theory, Numerical Analysis

Magnus, Amy L., Research Assistant Professor of Mathematics
BS, MS, PhD (Air Force Institute of Technology)
Computational Intelligence, Biometrics, Information Fusion, Constraint Programming

Morrill, Dana F., Maj, Assistant Professor of Mathematics
BS, MS, PhD (Air Force Institute of Technology)
Numerical Analysis, Fluid Mechanics

Nunnally, Beau A., Maj, Assistant Professor of Statistics
BS, MS, PhD (Air Force Institute of Technology)
Biostatistics, Classification Systems

Oxley, Mark E., Professor of Mathematics
BS, MS, PhD (North Carolina State University)
Partial Differential Equations, Wavelets, Information Fusion

Quinn, Dennis W., PE, Professor Emeritus of Mathematics
BS, MS, PhD (University of Delaware)
Partial Differential Equations, Numerical Analysis, Intra-Cellular Modeling, Pharmacokinetics

Reynolds, Daniel E., Assistant Professor Emeritus of Statistics
BA, MS, MS (Wright State University)
Environmental Statistics, Design of Experiments, Linear Models

Schubert Kabban, Christine M., Associate Professor of Statistics
BS, MBA, MS, PhD (Air Force Institute of Technology)
Biostatistics, Generalized Linear Models, Classification Methods, Information Fusion

Turner, Jonathan S., Capt, Assistant Professor of Statistics
BS, MS, MS, PhD (Air Force Institute of Technology)
Analysis, Combinatorics, Optimization

White, Edward D. III (‘Tony’), Professor of Statistics
BS, MAS, PhD (Texas A&M University)
Biostatistics, Design of Experiments, Linear Models, Regression

Wood, Aihua W., Professor of Mathematics
BS, MS, PhD (University of Connecticut)
Partial Differential Equations, Electromagnetics, Rarefied Gas Dynamics
Projected Course Offerings

Academic Year 2019-2020

**MATHEMATICS (MATH)**

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**PROBABILITY AND STATISTICS (STAT)**

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The numbers 1,2, etc. denote the number of sections of a course usually offered that quarter. An “O” or “E” designate an odd or even year, if the course is taught alternating years. The pound sign (#) indicates that the course usually attracts little interest from students but will be offered in the indicated quarter if enough interest is shown. An asterisk (*) indicates that one of the sections is for Distance Learning only. Course numbers ending with ‘A’ designate provisional courses.
Miscellaneous Policies

Diagnostic Examination: Entering master's students in the school normally arrive five weeks prior to the start of an academic quarter. During this time, every student takes a mathematics diagnostic examination. The results are used by students and advisors as an aid in selecting the most suitable sequence of mathematics courses, particularly the first course. The exam for engineering, science, and mathematics majors covers the standard topics from elementary calculus while the exam for managerial majors covers elementary algebra.

Review Courses: Master’s students entering the school are usually offered a rather intensive four week non-credit review of undergraduate subjects relevant to their programs prior to the start of the regular academic year. The mathematics reviews are offered via Canvas. These are pre-recorded lectures by department faculty; periodic quizzes have been included to aid in the review process. The name and contact information for a professor in the department is also supplied in case the student has questions about the material. The reviews come in four modules: algebra, calculus, differential equations, and linear algebra. Most students review two of the modules although some will study only one.

Special Studies Courses: The department occasionally offers special studies courses to enable students to pursue topics not covered in regularly scheduled courses. The offering of a special study (MATH/STAT 699 or MATH/STAT 899) in a particular quarter depends on the desires of the students, approval of the faculty advisor and approval of the department head. The number of credit hours may vary as appropriate. In general, a regularly scheduled class will not be offered as a special study class so that the student who wants to take such a class out of its normal rotation will not have it approved.

Ph.D. Mathematics Requirement: The AFIT doctoral program has a mathematics requirement. This requirement may be met by successfully completing (grade of 'B' or better) two mathematics/statistics (MATH/STAT) courses at AFIT numbered 600 or above which have been approved by the student’s advisor. Courses from DAGSI partner institutions, if approved, may be used to meet this requirement. In this case, the student must petition the AFIT Department of Mathematics and Statistics, preferably in advance, to approve such DAGSI courses as being appropriate in content and level. The test of appropriateness is whether the course would be properly offered by an applied mathematics department in a school of engineering.
Course Descriptions

Mathematical Analysis Courses (MATH)

MATH 302: Elementary Differential Equations
Credit: 4, 4 lecture, 0 lab
Prerequisite: Calculus
This course is an introduction to ordinary differential equations. Topics include linear first-order differential equations, linear second-order homogeneous differential equations with constant coefficients, the method of undetermined coefficients for nonhomogeneous second-order equations, the method of variation of parameters for nonhomogeneous second-order equations, power series solutions of nonconstant coefficient differential equations, an introduction to eigenvalues and eigenvectors for matrices, systems of first-order linear equations, reduction of linear differential equations to a first-order system, and solution of linear differential equations using Laplace transforms.
DIFFERENTIAL EQUATIONS, (Schaum’s Outline Series), Bronson

MATH 504: Differential Equations of Mathematical Physics
Credit: 4, 4 lecture, 0 lab
Prerequisite: None
This course builds proficiency with series solutions for ordinary differential equations having variable, complex coefficients. It provides specific information on Bessel and Legendre functions, Laguerre and Hermite polynomials. Other special functions of mathematics are introduced including gamma and beta functions. The course covers the needed topics in complex variables such as analytic functions, singularities, power series expansions, contour integration and residue theory.
MATHEMATICAL METHODS FOR PHYSICISTS, Arfken

MATH 508: Applied Numerical Methods
Credit: 4, 4 lecture, 0 lab
Prerequisite: None
APPLIED NUMERICAL ANALYSIS, Gerald and Wheatley
MATH 509: Mathematical Methods in the Physical Sciences  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: None*  
This course covers basic topics in linear algebra and the calculus of several variables. Topics from linear algebra include matrix algebra, solutions of systems of linear equations, real vector spaces, and linear transformations between real vector spaces. Topics from several variable calculus include partial differentiation, directional derivatives, functional transformations and Jacobians, maxima and minima, and integration in two and three variables.  
*MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES, Boas*

MATH 511: Methods of Applied Mathematics I  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: None*  
*ADVANCED ENGINEERING MATHEMATICS, Kreyszig*

MATH 513: Methods of Applied Mathematics II  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: MATH 511*  
*ADVANCED ENGINEERING MATHEMATICS, Kreyszig*

MATH 521: Applied Linear Algebra  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: None*  
Algebra of matrices, the theory of finite-dimensional vector spaces, and basic results concerning eigenvalues and eigenvectors with particular attention given to topics that arise in applications.  
*LINEAR ALGEBRA AND ITS APPLICATIONS, Strang*
MATH 600: Mathematical Analysis  
*Credit:* 4, 4 lecture, 0 lab  
*Prerequisite:* None  
This course provides the transition from elementary calculus to advanced courses (6XX, 7XX, 8XX) which require mathematical analysis with rigor. Topics include basic notions of set theory, point set topology, limits and continuity, derivatives, functions of bounded variation, Riemann-Stieltjes integration, uniform convergence of sequences and series of functions and their consequences and Lebesgue measure and integration theory.  
MATHEMATICAL ANALYSIS, Apostol  

MATH 601: Complex Analysis  
*Credit:* 4, 4 lecture, 0 lab  
*Prerequisite:* MATH 600 or MATH 602  
Introduction to the theory of complex variables; analytic functions, elementary functions and their geometry; integrals; power series, residues and poles; conformal mapping; applications.  
INTRODUCTION TO COMPLEX ANALYSIS, Silverman  

MATH 602: Modern Applied Mathematics I  
*Credit:* 4, 4 lecture, 0 lab  
*Prerequisite:* None  
Introduction to the foundations and applications of modern applied mathematics for students of applied science. Topics include distribution theory and Green's functions applied to one-dimensional boundary value problems, classical and weak solutions, alternative theorems, functions and transformations, Banach and Hilbert spaces, linear functionals, basic properties of linear and metric spaces including topology, continuity, differentiability, convergence of sequences and series of functions.  
GREEN'S FUNCTIONS AND BOUNDARY VALUE PROBLEMS, Stakgold  

MATH 604: Modern Applied Mathematics II  
*Credit:* 4, 4 lecture, 0 lab  
*Prerequisite:* MATH 602  
This is a course in applied functional analysis. Topics include linear operator theory and applications to (approximate) solutions of boundary value problems of applied science, closed operators, the inverse operator, adjoint and compact operators, spectrum, contraction mappings, Fredholm integral equations.  
GREEN'S FUNCTIONS AND BOUNDARY VALUE PROBLEMS, Stakgold
MATH 605: Nonlinear Differential Equations  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** MATH 600 or MATH 602  
Topics include linear systems with an introduction to phase space analysis, existence theory, stability of linear and almost linear systems. Lyapunov's second method, applications to nonlinear problems and optimal control theory, bifurcation theory and chaos.  
*INTRODUCTION TO NONLINEAR DYNAMICAL SYSTEMS AND CHAOS, Wiggins*

MATH 607: Calculus of Variations  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** MATH 600 or MATH 602  
Topics include a study of functionals, fixed and variable end point problems, canonical forms of the Euler equations and related topics, sufficient conditions for a weak extremum, fields, sufficient conditions for a strong extremum, variational problems involving multiple integrals, direct variational methods, and applications.  
*CALCULUS OF VARIATIONS, Gelfand and Fomin*

MATH 611: Introduction to Partial Differential Equations  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** MATH 600 or MATH 602  
Introduction to the fundamental concepts of partial differential equations and applications emphasizing the use of these basic concepts. Topics considered include classification, reduction to canonical form, existence of solutions, variational principles, methods of obtaining solutions of the basic types of equations using analytical methods. Some numerical methods are presented.  
*PARTIAL DIFFERENTIAL EQUATIONS - AN INTRODUCTION, Colton*

MATH 621: Linear Algebra  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** MATH 521 or MATH 523  
Basic algebraic properties of vector spaces and matrices, including dimension and bases, linear transformations, determinants, similarity and congruence, solution of linear systems of equations, generalized inverses, singular value decompositions, Jordan normal form, norms and inner products.  
*LINEAR ALGEBRA, Hoffman and Kunze*
MATH 631: Algebraic Structures  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: None  
An introduction to the algebra of semigroups, monoids, groups, rings, integral domains, fields and categories. Emphasis is placed on gaining a fundamental understanding of these basic algebraic structures so that the successful student will be able to apply the material in familiar and unfamiliar settings.  
ALGEBRA, MacLane and Birkhoff

MATH 633: Graph Theory  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: None  
An introduction to the theory and application of graphs. Topics include introductory concepts and definitions, digraphs, connected and disconnected graphs, graph traversals, connection problems, tree, planar and nonplanar graphs, Eulerian and Hamiltonian graphs, coloring problems, graph isomorphisms, multigraphs.  
INTRODUCTION TO GRAPH THEORY, 2nd ed, West

MATH 672: Numerical Linear Algebra  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: Calculus, linear algebra, and working knowledge of a scientific programming language  
NUMERICAL LINEAR ALGEBRA, Trefethen and Bau

MATH 674: Introduction to Numerical Analysis  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: Calculus, linear algebra, and working knowledge of a scientific programming language  
Roots of nonlinear equations, interpolation and approximation of functions, techniques for numerical integration and differentiation, techniques for solving ordinary differential equations, error estimates and convergence analyses for each topic.  
NUMERICAL METHODS FOR SCIENTIFIC COMPUTING, Novak
MATH 676: Numerical Analysis for Partial Differential Equations  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: Multivariable calculus, ordinary differential equations, linear algebra, and working knowledge of a scientific programming language*  
**Numerical Methods for Scientific Computing, Novak**

MATH 699: Master's Level Special Study  
*Credit: 1-12, 0 lecture, 0 lab*  
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

MATH 705: Linear Functional Analysis  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: MATH 600 and either MATH 621 or MATH 672*  
Introduction to metric spaces and normed linear spaces, operators and functionals on a Banach space, dual space; concrete representations and applications in Hilbert space, Hahn-Banach theorem, Open Mapping theorem, Banach-Steinhaus theorem, Closed Graph theorem, and topics in spectral theory.  
**Linear Operator Theory in Engineering and Science, Naylor & Sell**

MATH 799: Thesis Research  
*Credit: 1-12, 0 lecture, 0 lab*  
*Prerequisite: None*  
The topic for an independent study is selected from a wide variety of problems usually of current interest to the Air Force. The results of the study are reported in a thesis written under the supervision of a departmental faculty member and are presented in a formal oral report. Ordinarily this study extends over 4 quarters and no credit is given until the end of the last quarter.

MATH 831: Mathematical Optimization and Control  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: MATH 705*  
Modern Banach space formulation of optimization and control problems; calculus in Banach spaces; Gateaux and Frechet derivatives; optimization of functions. The
geometric approach to optimal estimation in a Hilbert space; the global and local theory of constrained optimization in a Banach space, iterative methods of optimization.

OPTIMIZATION BY VECTOR SPACE METHODS, Luenberger

MATH 899: Doctoral Level Special Study
Credit: 1-12, 0 lecture, 0 lab
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

MATH 999: Dissertation Research
Credit: 1-99 (Up to 12 credits per quarter)
Prerequisite: Approval of Research Advisor
Dissertation research conducted in mathematical analysis, including both the research itself and the preparation and defense of the prospectus and dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters. Remark: This course is graded on a P (progress) or U (unsatisfactory) basis.
Probability and Statistics Courses (STAT):

**STAT 521: Applied Statistical Data Analysis**  
*Credit: 5, 4 lecture, 2 lab*  
*Prerequisite: None*  
This course provides statistical tools for the analysis of data in the decision-making process. The course covers descriptive statistics, probability theory, and statistical inference. Concepts discussed include methods on how to specify what data is wanted, collect data, extract information from existing sources of data, test the validity of key concepts, estimate problem parameters, and relate one decision variable to another (ANOVA and regression).  
STATISTICS FOR BUSINESS AND ECONOMICS, McClave, Benson, and Sincich

**STAT 525: Applied Statistics for Managers I**  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: None*  
This course covers descriptive statistics, probability theory and statistical inference. Descriptive statistics covers both numerical and graphical techniques to illustrate data. Probability theory covers the theoretical underpinnings of both discrete and continuous random variables. Statistical inference includes topics such as the central limit theorem, confidence interval and hypothesis testing (one sample and two), and nonparametric techniques.  
STATISTICS FOR BUSINESS AND ECONOMICS, McClave, Benson, and Sincich

**STAT 535: Applied Statistics for Managers II**  
*Credit: 4, 3 lecture, 2 Lab*  
*Prerequisite: STAT 525*  
Statistical methods needed to gather, interpret and apply data in the decision making process are presented. Concepts discussed include methods on how to: specify what data is wanted, collect data, extract information from existing sources of data, test the validity of key concepts, make intelligent estimates of major problem parameters, and relate one decision variable to another (ANOVA and regression).  
STATISTICS FOR BUSINESS AND ECONOMICS, McClave, Benson, and Sincich
STAT 583: Introduction to Probability and Statistics

*Credit*: 4, 4 lecture, 0 lab

*Prerequisite*: None

Basic concepts of probability and statistics with applications are covered. Topics include permutations and combinations; random variables; probability distributions; estimation and confidence intervals; hypothesis testing. INTRODUCTION TO PROBABILITY AND STATISTICS, Milton and Arnold

STAT 586: Probability Theory for Communication and Control

*Credit*: 4, 4 lecture, 0 lab

*Prerequisite*: None

Selected topics from probability theory are introduced as a basis for applications in the analysis and design of modern communication and control systems. Topics include the concepts of sample spaces, random variables, random vectors, probability densities, probability distributions, discrete and continuous distributions, expectation and moments, characteristic functions, transformations of random variables and vectors, multivariate normal distribution. STATISTICAL INference, Casella and Berger

STAT 587: Applied Probability and Statistical Analysis

*Credit*: 4, 4 lecture, 0 lab

*Prerequisite*: None

This course presents the basic concepts of probability and statistics. Emphasized topics are basic probability axioms and laws, discrete and continuous random variables, joint probability distributions, expectations, conditional probability, the central limit theorem, sampling theory, estimation, and hypothesis testing. MATHEMATICAL STATISTICS W/ APPLICATIONS, Wackerly, Mendenhall, & Scheaffer

STAT 601: Theory of Probability

*Credit*: 4, 4 lecture, 0 lab

*Prerequisite*: STAT 583 and either MATH 509 or MATH 511

Topics include an introduction to probability theory, distributions and expectations of random variables, moment-generating functions, joint distribution of functions of several random variables, transformations of random variables, conditional expectation and conditional density functions, order statistics, and limit theorems. STATISTICAL INference, Casella and Berger
STAT 602: Mathematical Statistics  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: STAT 601  
This course provides the student with a solid foundation in the basic concepts of mathematical statistics. Topics include tests of hypotheses, point and interval estimation, sufficient statistics, uniform minimum variance unbiased estimates, Cramer-Rao inequality, and convergence theorems.  
STATISTICAL INFERENCE, Casella and Berger  

STAT 641: Analysis of Variance  
Credit: 4, 3 lecture, 2 lab  
Prerequisite: STAT 602, STAT 696, and either MATH 521 or MATH 621  
This course introduces classical analysis of variance (ANOVA) techniques, which includes one-way, two-way and three-way ANOVA. Additionally, an introduction to the design of experiments will be presented (i.e., full/fractional factorial, split-plot, and incomplete-block designs).  
APPLIED LINEAR STATISTICAL MODELS, Kutner, Nachtsheim, Neter, and Li  

STAT 642: Computational Statistics  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: STAT 602  
A detailed examination of essential statistical computing skills needed for research and applications. Students will use software tools to develop algorithms for solving a variety of statistical problems using resampling and simulation techniques such as the bootstrap, Monte Carlo methods and Markov chain methods for approximating probability distributions.  
COMPUTATIONAL STATISTICS, Gentle  

STAT 643: Nonparametric Statistics  
Credit: 4, 4 lecture, 0 lab  
Prerequisite: STAT 583 and STAT 602  
This course teaches the fundamental techniques and concepts used in modern nonparametric analysis. Topics include nonparametric tests, confidence intervals, density estimation, regression, resampling methods, smoothing and classification.  
NONPARAMETRIC STATISTICS W/ APPLICATION TO SCIENCE AND ENGINEERING, Kvam and Vidakovic
STAT 644: Categorical Data Analysis  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: STAT 696 and either STAT 583 or STAT 602*  
Introduction to the theory and methods used in the modeling and analysis of categorical response variables. Topics include contingency tables, logistic and log-linear models, measures of association and agreement, and standard classification methods such as discriminant analysis, clustering and regression trees.  
CATEGORICAL DATA ANALYSIS, 3rd ed, Agresti

STAT 645: Bayesian Inference  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: STAT 602*  
This course introduces the philosophical and computational aspects of Bayesian statistics. Specific topics are choice of priors, posterior analysis, prediction, and computational methods such as Markov chain Monte Carlo (MCMC).  
BAYESIAN DATA ANALYSIS, 3rd ed., Gelman, et al

STAT 687: Mathematics of Reliability Theory I  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: STAT 602*  
Reliability models, reliability estimation, exponential and Weibull models, sequential life testing, Bayesian reliability in testing and design, goodness-of-fit tests, accelerated testing, reliability growth models.  
STATISTICAL METHODS FOR RELIABILITY DATA, Meeker and Escobar

STAT 694: Design of Experiments  
*Credit: 4, 4 lecture, 0 lab*  
*Prerequisite: STAT 696 or MATH 521 or MATH 523 or MATH 621 or MATH 672*  
This course gives an introduction to the linear statistical model and its associated forms of inference with special emphasis on analysis of variance models. The classical experimental design models are analyzed with emphasis on fractional factorial designs and their application to engineering problems. The student will be able to pose a research question in statistical terms and design an experiment to answer that question including determination of expected mean squares and F-tests.  
DECISION OF EXPERIMENTS: STATISTICAL PRINCIPLES OF RESEARCH DESIGN AND ANALYSIS, Kuehl
STAT 696: Applied General Linear Models  
**Credit:** 4, 3 lecture, 2 lab  
**Prerequisites:** STAT 583  
Theory and application of the general linear statistical models. Population distribution and parameters are tested using regression and analysis of variance in the context of the general linear model. Topics covered include general regression and correlation analysis, basic analysis of variance, and multifactor analysis of variance.  
APPLIED LINEAR REGRESSION MODELS, Kutner, Nachtsheim, and Neter

STAT 699: Master's Level Special Study  
**Credit:** 1-12, 0 lecture, 0 lab  
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

STAT 701A: Advanced Probability  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** STAT 601 and MATH 600  
This course provides a measure theoretic introduction to probability theory. It details how to construct probability measures and discusses distribution functions, characteristic functions, independence, and zero-one laws. Additional topics include: sequences of independent random variables, strong law of large numbers, the central limit theorem, conditional expectation, and martingales.  
PROBABILITY AND MEASURE, Billingsley

STAT 702A: Advanced Inference  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** STAT 602  
This course covers advanced topics in statistical inference. Topics include types of convergence, various limit theorems, aspects of point estimation, asymptotic confidence intervals and hypothesis testing, decision theory and risk optimality.

STAT 703: Theory of Linear Models  
**Credit:** 4, 4 lecture, 0 lab  
**Prerequisite:** STAT 602 and STAT 696  
This course provides a rigorous treatment of the theory of linear models. Topics include best linear unbiased estimator, minimum variance unbiased estimate, sampling distribution of estimates, normal equations, testing hypothesis of linear
parametric functions, tests for generalized linear models, multifactor analysis of variance, k-way analysis of variance, polynomial regression, estimation and testing in general Gauss-Markov models.

**STAT 799: Thesis Research**  
*Credit: 1-12, 0 lecture, 0 lab*  
*Prerequisite: None*  
The topic for an independent study is selected from a wide variety of problems usually of current interest to the Air Force. The results of the study are reported in a thesis written under the supervision of a departmental faculty member and are presented in a formal oral report. Ordinarily this study extends over 4 quarters and no credit is given until the end of the last quarter.

**STAT 899: Doctoral Level Special Study**  
*Credit: 1-12, 0 lecture, 0 lab*  
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**STAT 999: Dissertation Research**  
*Credit: 1-99 (Up to 12 credits per quarter)*  
*Prerequisite: Approval of Research Advisor*  
Dissertation research conducted in probability or statistics, including both the research itself and the preparation and defense of the prospectus and dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters.

**TENC 799: Thesis Completion**  
*Credit: 12*  
Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENC 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Mathematics and Statistics. The grade assigned to this course is the official thesis grade.