SOME UPPER DIVISION AND GRADUATE COURSES
IN THE MATHEMATICS & STATISTICS DEPARTMENT
AT THE UNIVERSITY OF NEVADA RENO

NOTE 1: *If you wish to speak to someone regarding any particular course, names of appropriate faculty members appear in parentheses to the right of each course name.*
NOTE 2: *For understanding prerequisites –*
STAT 152 = Statistics for non-mathematicians
MATH 283 = Calculus III
MATH 285 = Differential Equations
MATH 310 = Undergraduate Analysis I
MATH 311 = Undergraduate Analysis II
MATH 330 = Linear Algebra
MATH 331 = Groups, Rings, and Fields
MATH/STAT 352 = Probability and Statistics
NOTE 3: *In Fall 2003 several of our course numbers were changed.*
MATH 461/661 = the former MATH 451/651
MATH 466/666 = the former MATH 483/683
MATH 467/667 = the former MATH 484/684
MATH 488/688 = the former MATH 423/623
NOTE 4: *Courses here are ordered by their NUMBER, not their (Math vs Stat) prefix.*

MATH 410/610 Complex Analysis (Johnson or Kumjian)
Complex analysis is the study of calculus on the complex numbers. While the theory superficially resembles ordinary calculus of functions on the real numbers, the details and applications are very different. The theory is much richer and more elegant than ordinary calculus, and there is some beautiful geometry involved which has unexpected applications to problems in physics and engineering. Ideas and techniques from complex analysis are used throughout pure and applied mathematics, and in many scientific fields. The familiar pictures from fractal geometry are made using complex analysis.
Prerequisites: MATH 283 required; MATH 310 recommended.

MATH 420/620 Mathematical Modeling (Herald, Mortensen, Pinsky, Telyakovskiy)
Students will solve real problems from science, engineering, business, medicine, and agriculture using advanced mathematical techniques (nonlinear optimization, dynamical systems, and random processes) and modern computational tools (MAPLE, LINGO, MINITAB). ***Prerequisites***: MATH 283, MATH/STAT 352 or MATH 461. Major capstone course. [MM 2001]

MATH 430/630 Linear Algebra II (Jabuka or Olson)
The linear algebra behind the following applications will be developed:
1) Network design.
2) Least squares approximations for statistical analysis.
3) The Fast Fourier Transform.
4) Eigenvalues, Eigenvectors, Diagonalization and Jordan Cannonical Forms for matrix exponentiation (differential equations) and powers of matrices (for finite difference

equations).
5) Finite Element Methods.
6) Minimization/Maximization problems.
7) Machine efficient methods for finding eigenvectors and solving the matrix equation $Ax = b$. [This includes knowing when the coefficient matrix is ill conditioned so that numerical results are likely to be of questionable accuracy, as well as being able to take advantage of certain features of A that occur in various applied problems to improve accuracy and efficiency].

This course will be highly motivated by applications and examples. ***Prerequisite***: MATH 330.

MATH 440/640 Topology (Deaconu, Jabuka, Naik)
A topological space is a collection of points and a structure that endows them with some coherence, in the sense that we may speak of nearby points or points that in some sense are close together. We will start by recalling some general notions about sets and functions. Then we will discuss metric spaces, which are natural generalizations of the real line with the usual distance between two points. Finally, we will introduce the general concept of a topological space, studying the notions of continuity, connectedness and compactness. We will have plenty of examples, including familiar curves and surfaces. ***Prerequisite***: MATH 310.

MATH 441/641 Algebraic Topology (Jabuka or Keppelmann)
Topology is popularly known as "the rubber sheet geometry". Topologists are jokingly referred to as mathematicians who can't distinguish between a coffee cup and a doughnut, since the surface of one can be continuously stretched ijnto the surface of the other. A doughnut and a two-holed doughnut cannot be stretched into one another; the same goes for a once-punctured disc and a twice-punctured disc. Perhaps surprisingly, group theory (see MATH 331) proves to be a useful tool in the study of questions like this. In this course we will learn two ways of associating algebraic objects to a topological space, namely homology and homotopy. We will study fundamental groups, covering spaces, and homology theory. [SN 2003] ***Prerequisite***: MATH 440/640. ***Co-requisite***: MATH 331.

MATH 442/642 Differential Geometry (Herald or Jabuka)
The course will be of interest to: MATH students who want to use their calculus and linear algebra skills to study fascinating geometric problems; COMPUTER SCIENCE students who are into computer graphics and want to come to a deeper understanding of the shapes of curves and surfaces in space; for PHYSICS students who want an introduction to the math behind much of modern theoretical physics. Differential Geometry is used in such diverse fields as Relativity Theory, Mechanics, Control Theory, Computer Graphics, much of Theoretical Physics, as well as in other branches of Mathematics. ***Prerequisites***: MATH 311 *or* the consent of the instructor. [CH 2001]

MATH 449/649 Geometry and Topology -- Knot Theory (Jabuka or Naik)
We will study the mathematical theory of knots and links and discuss the applications to biology, chemistry and physics. This course will not have any prerequisites, however some background in 300 level math courses (eg. MATH 310, MATH 330) will be necessary. ***Prerequisites***: Consent of the instructor. A corequisite of MATH 311 or 441/641 is strongly recommended. Familiarity with elementary group theory will be useful, but not required. [SN 2001]

STAT 452/652 Statistics: Continuous Methods (Alparslan, Kozubowski, Panorska, Zaliapin)
"Statistics is the art of making numerical conjectures about puzzling questions." Is the medicine effective? What is the association between the Sierra snow pack and the clarity of Lake Tahoe? Is there a trend in inflation rate? What drives development around Reno? Why does a casino make a profit on the roulette?

In this course you will learn to choose appropriate models for real world situations, exercise these models using appropriate mathematical and computer techniques, and interpret the results in plain language. The topics covered in this course include: goodness of fit testing, methods of estimation, parametric and nonparametric approaches to correlation and multivariate regression, trend analysis, analysis of variance, analysis of categorical data. There will be a significant emphasis on hands-on statistical computations and data analysis and modeling methods using a statistical package (MINITAB). No prior programming experience is required.

Text: Devore, Jay, L. *Probability and Statistics for Engineering and the Sciences*, 5th Ed., Duxbury. The book will be supplemented with information available on the web.
Prerequisites: MATH/STAT 352 or STAT 467/667 or permission of instructor.
Note: STAT 452 is required for BA and BS in Mathematics, statistics option, while STAT 652 is required for MS in Mathematics, Statistics option. [TK 2005]

MATH 461/661 Probability Theory (Formerly Math 451/651) **(Alparslan or Kozubowski)**
Probability models are used to represent river flows, customer arrivals, atoms, chemical reactions, epidemics, election results, and stock markets. Probability theory is the basis for all of these mathematical models. An infinite series represents the average number of customers arriving this month. An integral gives the average jump in daily stock market prices. A double integral gives the probability that the river will rise higher this year than last year. In this course you will learn to apply the tools of calculus and analysis to problems in probability. Topics to be discussed should include: probability space axioms; random variables; expectation; univariate and multivariate distribution theory; sequences of random variables; Tchebychev inequality; the law of large numbers and the central limit theorem. MATH 461/661 is a beautiful chapter of pure mathematics, as well as the foundation for stochastic processes, statistics, econometrics, and quantum mechanics. Take this course and prepare for a brilliant future in an uncertain world. [TK 2005]
Prerequisite: MATH 283.

Note: MATH 461 is required for BA and BS in Mathematics (all options) while MATH 661 is required for MS in Mathematics, Statistics option.

MATH 466/666 Numerical Methods I (Formerly Math 483/683) **(Mortensen, Olson, Telyakovskiy)**
This course is a one semester introduction to the subject of Numerical Analysis. Numerical analysis concerns algorithms and methods for obtaining solutions to mathematical problems. We will survey many of the tools and techniques of the field. Some of the topics include interpolation, integration, linear systems, differences, differential equations, nonlinear equations and optimization. This course will be a "hands-on" course focusing on use of the computer, with much less emphasis on theory (an introduction to FORTRAN will be provided). The student will be able to leave this course able to obtain solutions to seemingly intractable problems and understand the basis of many large software packages now available. ***Prerequisite***: MATH 330.

MATH 467/ 667 Numerical Methods II (Formerly Math 484/684) **(Mortensen, Olson, Telyakovskiy)**
Numerical solution of ordinary differential equations; boundary value problems; finite difference methods for partial differential equations; finite element method. Since MATH 466/666 is NOT a prerequisite for this course, there will be a brief review of relevant topics from MATH 466/666, including numerical differentiation and integration. ***Prerequisite***: MATH 285 or equivalent, and a knowledge of computer programming. ***Note***: An introduction to Maple and Matlab will be provided. [JM 2003]

STAT 467/667 Statistical Theory (Kozubowski or Panorska)
Deepen your understanding of statistics. Discover the interesting mathematics behind the common statistical procedures used in practice such as estimation, testing hypotheses, and linear regression. Topics to be discussed should include multivariate probability distributions; details of point and interval estimation, including the methods of moments and maximum likelihood; derivations of common statistical tests and the corresponding power calculations; mathematical details of the method of least squares and the corresponding linear regression problems. ***Prerequisites***: MATH 283, 330, and either MATH/STAT 352 or MATH 461/661.

Note: STAT 467 is required for BA and BS in Mathematics, Statistics option.

MATH 474/674 Sets and Numbers (Deaconu, Pfaff)
After a brief review of logic, we present two axioms for set theory, the Axiom of equality and the Axiom of set formation. Algebra of sets, relations, functions, equivalence relations, partitions, and arbitrary unions and intersections are studied with emphasis on proving the appropriate theorems about them. With set theory established on a more or less secure foundation, we proceed through a series of constructions. In succession, we build set theoretical models for the Natural Numbers, Integers, Rational Numbers (Here the students do all the work since the process is similar to what we went through for the Integers), Reals, and Complex Numbers (again, it is up to the students to prove the theorems here). The Reals are constructed using Dedekind cuts, which forces them to come to grips with reasoning with inequalities and mixed quantifiers. The Completeness Property of the Reals is proved, using sups and infs. ***Prerequisite***: MATH 373 [DP 2001]

MATH 475/675 Euclidean and non-Euclidean Geometry (Herald, Jabuka, Pfaff)
After showing dramatically how dangerous it is to reason from a picture, we introduce axioms gradually and examine their consequences. Emphasis is placed not only on the theorems of geometry, but also on metatheorems about independence. Elementary Absolute Geometry is studied rigorously, including the concepts of betweenness, coordinate systems, separation, SAS, and the Exterior Angle Theorem. After a discussion of the history of Euclid's Fifth Postulate, we introduce the Klein and Poincare models to motivate the study of Hyperbolic Geometry. After a brief digression on the completeness of the Reals and the Archimedean Property, we introduce the Hyperbolic Parallel Postulate and spend the rest of the semester coming to grips with the properties of this new world. As always, throughout, the emphasis is on proofs, how to find them and how to write them. ***Prerequisite***: MATH 373 [DP 2001]

MATH 485/685 Combinatorics and Graph Theory (Quint)
Combinatorics is the study of arrangements, patterns, designs, assignments, schedules, connections, and configurations. Graph theory is the study of networks. Together these areas constitute one of the fastest growing fields of modern mathematics. We present the basic mathematical theory of these areas, together with many applications. Topics Covered: Counting rules; generating functions; recurrence relations; inclusion-exclusion; pigeonhole principle; Ramsay theory; fundamental graph theory concepts (connectedness, coloring, planarity); Eulerian and Hamiltonian chains and circuits. ***Prerequisites***: MATH 330 or consent of the instructor. MATH 285 is recommended. No previous background in combinatorics or graph theory assumed. [TQ 2001]

MATH 486/686 Game Theory (Quint)
Game theory is the mathematical modeling and analysis of conflict situations involving more than one player. In particular, we study issues such as the existence of equilibria and the formation of coalitions in such situations. Applications will be given in economics and political science. Topics Covered: Extensive and strategic form games; Nash equilibrium; repeated games; matrix/bimatrix games; minimax theorem; TU/NTU solution; marriage, college admis-sions, and houseswapping games; core and Shapley value; power indices; NTU games. ***Prerequisites***: MATH 330 or consent of the instructor. Background in linear programming (MATH 487/687 or 751) would be helpful but is not required. No previous background in game theory assumed. [TQ 2001]

MATH 487/687 Deterministic Operations Research (Quint)
In MATH 487/687 we cover the techniques of deterministic operations research. Topics include linear and integer programming, shortest paths in a network, project scheduling, dynamic programming, deterministic inventory theory, and nonlinear programming. Although we will study the theory of linear programming (in particular the simplex method) and also that of nonlinear programming, much of the focus of the course will be on model formulation of applied problems. Students will go "on line", using LINDO and GINO to solve business-school style "cases". ***Prerequisites***: MATH 330 or permission of the instructor. [TQ 2003]

MATH 488/688 Differential and Difference Equations II (Formerly Math 423/623) **(Pinsky)**
Partial differential equations are often used in various disciplines to model complicated problems. The goal of this course is two-fold: to study how to interpret a partial differential equation, and to investigate various methods one can use to solve different types of partial differential equations (analytical methods for exact solutions and approximate methods for numerical solutions).

Topics include classification of partial differential equations, interpretations of the heat equation, the wave equation and Laplace's equation, solutions by various analytical methods (separation of variables, eigenfunction expansion, the sine and cosine transforms, the Fourier transform, the Laplace transform, method of characteristics, change of coordinates) and approximate methods (explicit and implicit finite difference methods). ***Prerequisite***: MATH 285.

MATH 713 Abstract and Real Analysis I (Blackadar, Kumjian, Naik)
The focus of this course will be to develop the modern theory of integration of real-valued functions based on Lebesgue measure. The Riemann integral, familiar from Calculus, does not behave well with respect to limits. The Lebesgue integral does, and this makes it well-suited as a tool in Modern Analysis and Probability theory. The syllabus follows:
1) Set Theory
2) The Real Number System
3) Lebesgue Measure
4) The Lebesgue Integral
5) Differentiation
6) The Classical Banach Spaces
Text: H. L. Royden, Real Analysis, 3rd Edition.
Prerequisites: Consent of the instructor. MATH 311 and 440/640 are recommended.

MATH 714 Abstract and Real Analysis II (Blackadar, Kumjian)
The focus of this course will be measure theory on general measure spaces and elementary functional analysis. Measure theory lies at the foundation of modern analysis and probability theory. **Topics covered**: Classical Banach spaces, measure spaces, convergence theorems, the Radon-Nikodym Theorem, the Fubini Theorem. **Text**: H. L. Royden, Real Analysis, 3rd Ed. ***Prerequisites***: MATH 713 or consent of instructor.

MATH 721 Nonlinear Dynamics and Chaos (Pinsky)
Dynamical systems theory explores modern ideas, techniques, and computer algorithms developed for modeling, analyzing and controlling the time-evolution of natural and man-made systems.

Pretend, for example, that you observe the initial state of a system modeling dynamics of connected elastic bodies or atoms in molecules, evolution of chemical reactions or competition in biology, ecology or economics, as well as problems in meteorology, hydrology or, say, laser physics. How do you predict the evolution of these kinds of dynamical systems? Although questions of this nature have guided progress in science for hundreds of years, emergence of chaos theory was a turning point in these studies resulting in the development of new thinking across science and engineering.

In this course, we will study how to describe and analyze some of complex phenomena arising in nonlinear systems using relatively simple analytical and numerical techniques. We attempt to make a sound connection of mathematical derivations and physical intuition and comprehend the behavior of various dynamic models arising in engineering and physical sciences.

First part of this course two-semester course starts with analysis of relatively simple nonlinear systems described by second order differential equations. We show that despite their relative simplicity, these models describe complex phenomena that have no analog in linear dynamics. Next we study the synchronization and competition of nonlinear modes, nonlinear resonances, local bifurcations undergoing in continuous and discrete models of natural and engineering systems and enter the area of nonlinear wave. ***Prerequisite***: MATH 330. MATH 285 is recommended. [MP 2003]

Math 722 Nonlinear Dynamics and Chaos (Pinsky)
The second part of this two-semester course centered on deeper study of bifurcation phenomena leading to development of chaotic behavior. In this connection, we study bifurcation and chaos in continuous Lorenz equations and discrete dynamical systems as well as introduce fractals and Mandelbrot and Julia sets. Essential time is dedicated to analysis of bifurcation and chaotic behavior in various applied systems such as optical resonators, chemical reaction, and communication models, as well as to control of chaotic systems. ***Prerequisites***: MATH 721. [MP 2003]

MATH 731 Modern Algebra I (Blackadar, Kumjian)
The Essence of Pure Mathematics. Some of the deepest (as well as most useful) theorems in Analysis, Topology and Applied Mathematics rely on algebraic concepts. The fundamental concept of symmetry in Physics and the other Sciences depends in an essential way on the mathematical notion of group. We will revisit the material of abstract algebra with the hope that it will provide a higher understanding of its concepts. We hope reach the cyclic decomposition theorem by the end of the semester, which has the Jordan decomposition theorem as one of its most important consequences. Thereafter we investigate the role of groups in field extensions (i.e. Galois Theory). If there is time we will explore category theory and its foundational role in mathematics. ***Prerequisites***: Consent of the instructor. We recommend MATH 330 and 331.

MATH 732 Modern Algebra II (Blackadar, Kumjian)
Continuation of MATH 731. ***Prerequisite***: MATH 731.

MATH 751 Operations Research I - Linear Programming and Extensions (Quint)
A *linear programming problem* is a problem in which one is to optimize a linear function (of n variables) subject to linear constraints. We define an algorithm for such problems, called the simplex algorithm, and prove that it converges. We investigate the theory of

duality and that of sensitivity analysis. We extend the simplex algorithm so as to be able to solve integer programming problems and fractional programming problems. Finally we cover topics in nonlinear programming, such as the linear complementarity problem and Kuhn-Tucker theory. ***Note***: The focus of this course is on theory, not applications. For the "applications" side of things, enroll in Math 487/687. ***Prerequisite***: MATH 310, 330. [TQ 2003]

MATH 752 Operations Research II – Stochastic Models (Quint)
In Math 752 we consider operations research models with a probabilistic component. In particular, we cover decision analysis, reliability theory, Markov Chains, queueing theory, and probabilistic inventory theory. We will also study some applications of these models. ***Prerequisites***: MATH 330 and MATH 461/661, or consent of the instructor.

IMPORTANT NOTE: MATH 751 is NOT a prerequisite for this course. [TQ 2001]

MATH 753 Stochastic Models and Simulation (Alparslan or Kozubowski)
Stochastic models are used to represent random processes which evolve over time. Inventory levels are modeled by a Markov chain. Decay times for radioactive particles are modeled by a Poisson process. The number of customers waiting in line is modeled by a Markov process. The diffusion of a chemical through the water table is modeled by a Brownian motion. The flood stage of the Truckee River is modeled by a time series. In this course you will learn to choose appropriate models for real world situations, exercise these models using appropriate mathematical and computer techniques, and interpret the results in plain language. Topics to be discussed include stochastic process models with applications; analytic and computer modeling techniques for Markov chains; Poisson and Markov processes; Brownian motion and special topics. ***Prerequisites***: MATH 330, MATH 461. [TK 2005]

STAT 754 Mathematical Statistics (Kozubowski or Panorska)
This introduction to classical mathematical statistics is intended to cover mathematical details of the basic problems of parameter estimation and testing hypotheses. Topics to be discussed include statistical models and applications; modes of convergence used in statistics; methods of point and interval estimation, including Bayesian inference; elements of large sample theory; unbiasedness, sufficiency, and completeness; hypothesis testing, including likelihood ratio tests, Neyman-Pearson lemma, and most powerful tests; introduction to linear models and special topics. ***Prerequisite***: MATH 311, 330, 461/661.

Note: This course is required for MS in Mathematics, Statistics option. [TK 2005]

STAT 755 Multivariate Data Analysis (Kozubowski or Panorska)
In various areas of science, researchers frequently collect measurements on several variables. In this course we shall discuss basic statistical techniques for analyzing such multivariate data. Our focus will be both understanding theoretical concepts and practical implementation of the methods on real data sets. Topics to be discussed should include sample geometry and random sampling, the multivariate normal and related distributions,

estimation of the mean vector and the covariance matrix, multivariate linear regression models, principal components, factor analysis, canonical correlation analysis, discrimination and classification, and cluster analysis. Basic knowledge of multivariate calculus, linear algebra, and probability/statistics are assumed. ***Prerequisites***: MATH 330, MATH 461/661. ***Co-requisite***: STAT 452/652.

Note: This course is required for MS in Mathematics, Statistics option.

STAT 756 Survival Analysis (Park)
Researchers in the engineering, actuarial, and biomedical sciences are often faced with the problem of analyzing failure time data which represent times to occurrence of point events such as failure of an electronic component in an engineering study, filing of a claim of an insured unit in an actuarial setting, or recovery of a patient in a clinical trial. In most of these cases, one will not be able to observe the exact failure times of all observations due to monetary or time constraints, but will only be able to observe censored data. In this course, statistical methods that will handle these censored data will be discussed. Methods will vary from tools used to analyze data from a single population to regression tools. There will be a balance of theory and applications for a better understanding and appreciation of the concepts of survival analysis. ***Prerequisite***: MATH 283 and MATH/STAT 352, or permission of instructor. ***Corequisite***: STAT 452/652. [IA 2001]

STAT 757 Applied Regression Analysis (Park)
Learn the basic concepts of linear regression analysis such as least-squares estimation and statistical inferential procedures for model parameters. Methods for checking the adequacy of the model (residual analysis) as well as choosing the best model in light of the data gathered will also be discussed. [TK 2005]

STAT 758 Time Series Analysis (Zaliapin)
Time series analysis concerns random quantities that evolve over time. Practical examples include temperature, rainfall, river flows, stock market prices, interest rates, unemployment levels, electrical signals, customer demand, and population. In this course we will survey analytic and computer methods for time series analysis. We will explore both the time domain (autocorrelation) and frequency domain (spectral) approach. ***Prerequisite***: MATH 311, MATH 330, and MATH/STAT 352, or permission of instructor. [TK 2005]

MATH 761 Techniques in Applied Mathematics (Olson or Telyakovskiy)
This course will serve as an introduction to mathematical techniques found in various fields of engineering and natural sciences. We will try to strike a balance between studying the mathematical aspects of the subject and dedicating an appropriate attention to empiric origins of our methods that should stimulate intuitive thinking and embrace multiple connections with important physically motivated problems.

We begin with Dimensional Analysis and Scaling and show its applications to problems from such diverse disciplines as chemical reactions, hydrodynamics, wave propagation and population dynamics, and also to mathematical modeling in certain softer fields where the explicit models are still unknown. We will follow with the perturbation techniques and consider their application to some of the problems already considered in this course. After that, we turn our attention to Calculus of Variations and subsequently to Integral Equations, Integral Transforms, and Green's function method. ***Prerequisites***: MATH 283, 285, and 330. MATH 488/688 is desirable. [MP 2003]

MATH 762 Techniques in Applied Mathematics (Olson or Telyakovskiy)
The second part of this two-semester sequence is centered on deeper study of various phenomena described by partial differential equations. In this broad area, we focus on analysis of dynamic behavior described by linear and nonlinear parabolic and hyperbolic PDEs as well as on analysis of more general wave phenomena occurred in continuous systems.

In this connection, we emphasize various perturbation and calculus of variation techniques that help reduce the complexity and furnish the mathematical analysis in a way consistent with physical intuition. We also explore connection between analytical and numerical techniques that leads to their fruitful cross-fertilizing. ***Prerequisites***: MATH 283, 285, and 330. MATH 488/688 and 761 are desirable but not mandatory. [MP 2003]

MATH 767 Advanced Mathematics for Earth Sciences
Applications of advanced mathematics for earth scientists and engineers. Includes elements of vector calculus, linear algebra, differential equations, probability, and statistics. These useful mathematical methods will be presented and applied in the context of real world problems. ***Co-requisite***: MATH 283 or equivalent [MM 2003]