Hopkins Applied Math and Stat Summary

Hi Ms. Dunbar,

Thank you very much for turning up this interesting state of affairs. I believe this will be OK for our purposes, but I do have one question. You say that in 1925 a 3 hour course was worth 6 points. But if points are like semester hours at other institutions and if 125 are needed to graduate, it looks more like 3 points would be for 3 hours (assuming hours are counting just in-class time and not homework time), not 6. A minor typo perhaps? Or have I missed something?

In any case, thank you for the work you have done for the Cajori Two Project.

Walter Meyer

On Jul 9, 2008, at 5:22 PM, Joy Dunbar wrote:

Prof. Meyer.

Although time consuming, this has been an interesting investigation into old JHU catalogs and commencement programs here in the Office of the Registrar. I was hoping to have a better answer for the early years, but here is what I've found.

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There are no catalogs prior to 1925 at which time the Bachelor's degree was awarded based on "points" with a note in the catalog that said this was "semester hours at other institutions". The requirement was 125 points, where basically the 3 hr course was 6 points. (There were exceptions for some courses and labs in some Courses of Study.)

By 1935 there was no more referral to "points", but only to satisfying a Course of Study as outlined by the major department. Looking at the Course of Study for many years, it was fairly consistent.

1945 and 1955 continued to grant the degree based upon the satisfactory completion of the outlined Course of Study.

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By 1965 a course was assigned semester credits with the Bachelor's degree requiring a minimum of 120 credits.

This remained consistent though the next 40 years.

No records or reports referred to the terms as anything but semesters.

I hope this is the information that you needed.

Joy

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Baltimore MD 21218

Walter Meyer <meyer1@adelphi.edu> 7/9/2008 3:23 PM >>>
Hi Ms. Dunbar,

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7.331 **Myth and Ritual**
7.334 **Art and Aesthetics in Anthropological Perspective**
7.336 **Anthropological Approaches to Folklore**
9.65 **Goethe's Faust in Translation**
9.86 **Literature and Society in Eighteenth-Century Germany**
9.90 **The Contemporary Scene**
9.311-12 **Introduction to Germanic Philology**
9.355 **German Literature in the Age of Goethe**
9.361 **Romanticism**
10.307 **Renaissance Humanism**
10.308 **Late Middle Ages**
10.314 **Italian Humanism**
10.316 **Reformation History**
14.32 **Science and Technology in Contemporary Society**
14.337 **Android: Artificial Human Beings in Literature and Myth from the Renaissance to the Present**
14.346 **Studies in Biology and Society: The Idea of Progress**
14.347 **Studies in Biology and Society**
14.348 **Health and Social Welfare in Western Society**
14.358 **Science, Magic, and Religion in Early Modern Europe**
14.360 **Science and Imaginative Literature**
15.20 **Aesthetics of the Film**
15.304 **History of Modern Philosophy: The 19th Century**
21.311 **Translation: History, Theory and Practice**
21.354 **Marxist Aesthetics**
21.364 **Autobiography: Proust, Leiris, Sartre, Lévi-Strauss**
21.612 **The Iconic and the Linguistic**
21.661 **An Historical Survey of Romance Linguistics**
22.301 **Auden Writing**
22.303 **The Fiction Writer's Situation in the Last Third of the 20th Century**
22.603 **The Modern Lyric**

The following courses will be offered at Goucher College:

331 Roman and English Satire
201 Digging the Greeks: An Introduction to Greek Archaeology
203 Societies in Crisis: The Worlds of Pericles and Caesar
2xx Alexander the Great, the "Pax Romana" and Christianity: The Beginnings of World Unity in Antiquity
213 Ancient Drama
216 The Epic
269 Classical Mythology and the Tradition

International Studies

See the Department of Political Science.

Semesters

Italian

See the Department of Romance Languages.

Mathematical Sciences

not same as math
see p 206

For three centuries the principal applications of mathematics have been to engineering and to the classical natural sciences: astronomy, physics, and chemistry. At the same time, these fields have been important sources of

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inspiration and direction in the development of mathematics. Although the classical natural sciences were the first fields in which mathematics was applied, there are today many others. For example, biology, operations research, demography, management science, economics, information science, psychology, health care systems, sociology, ecology, and computer science were until only recently either nonexistent or largely descriptive and nonquantitative. Now, however, mathematical methods and models are essential to each of them.

Because of the obvious differences between these fields and the older physical sciences, it is no surprise that somewhat different quantitative methods have proved appropriate to them. Some of the methods, such as combinatorial analysis, already existed but were given new vitality by the needs of new applications. Other methods, such as the techniques of analysis in the finite number systems used in large digital computers, had to be created. Now, as always in the history of science, inspiration flows both ways between theory and applications; this is as desirable as it is inescapable.

Basic mathematical methods remain essential in the new fields of application, of course, but a glance at any of their current journals reveals that many newer techniques are in wide use: Probability, mathematical programming, statistical analysis and inference, optimal control, stochastic processes, game theory, queueing theory, numerical analysis, information theory, combinatorics, finite and discrete mathematics, and decision theory. We shall refer to such fields of modern applied mathematics collectively as *the mathematical sciences.* It is across this spectrum of activities that the programs of instruction and research of the Department of Mathematical Sciences are spread.

At both the graduate and undergraduate levels the department's programs emphasize basic training in the mathematical disciplines so necessary for science and management in the 1970's. Students are encouraged to broaden their background and to develop their scientific intuition by electing a variety of courses in the applications. A typical program should prepare the student to continue a scientific career in either theoretical or applied work (or both).

The department has an undergraduate major leading to the B.A. degree and graduate programs leading to the M.A., M.S.E., and Ph.D. degrees. It also has a combined bachelor's-masters program under which exceptionally able undergraduates may be admitted early to simultaneous graduate work.

The Faculty

Professor David B. Duncan: general statistical theory and applications, applied statistical inference theory.

Professor Charles D. Flagle: operations research, decision theory, health systems analysis.

Professor Martin Greenberger: simulation methods in policy research, computer-communication networks.

Professor Roger A. Horn (Chairman): analysis, complex variables, probability.

Professor Rufus Isaacs: differential games, control theory, applied mathematics.

Professor Allyn W. Kimball: experimental statistics, biometry.

Professor Eliezer Naddor: operations research, inventory systems, computer science.

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Professor John P. Young: operations research, stochastic processes, queueing theory, health systems.

Associate Professor D. Jack Elzinga: optimization theory, mathematical programming, location theory, production scheduling.

Associate Professor Charles A. Rohde: general statistical theory, statistical inference in stochastic processes.

Associate Professor Richard M. Royall: statistical inference, nonparametric statistics, sampling theory.

Assistant Professor Richard Bartels: numerical analysis, optimization.

Assistant Professor James Case: differential games, many-player game theory, applied mathematics, mathematical economics.

Assistant Professor William H. Cunningham: combinatorics, discrete optimization.

Assistant Professor Susan D. Horn: decision theory, probability, large sample theory.

Assistant Professor William H. Farr: statistics, continuous time programming.

Assistant Professor Alan F. Karr: stochastic processes, probability.

Assistant Professor Albert Liebetrau: statistics, stochastic processes, categorical data.

Assistant Professor David Pyne: statistical inference, abstract mathematical programming.

Undergraduate Programs

A major in mathematical sciences includes a core of quantitative work of virtually universal applicability, a program of advanced work in areas of the student's choice, and the opportunity to choose an area for application of acquired technical skills. Students with an interest in quantitative studies will find this major sufficiently flexible to permit them to prepare for careers or graduate work in such diverse fields as actuarial science, business, computer science, economics, mathematics, medicine, operations research, physical or social science, and statistics. Sample programs appropriate to various areas of concentration are available in the department office.

Requirements for the Bachelor of Arts Degree

The requirements for the major are broadly stated, but it is important that each student have a definite plan for his or her academic program. With the advice and consent of the faculty adviser, each student will construct a program consistent with his or her goals which incorporates the requirements below. A written copy of this program should always be on file with the faculty adviser, although it may need to be revised and updated from time to time. Every departmental major must meet University requirements outlined in the front of the catalog. The departmental requirements are: (a) at least forty credits for courses coded (Q) including a core program consisting of: four semesters of elementary calculus, linear algebra, and advanced calculus; two semesters of probability and statistics courses with a calculus prerequisite; and one semester

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course in computing; at least eighteen credits must be for courses at or above the 300 level; (b) at least three semesters of course work in some one field of application of the mathematical sciences. The courses in (b) are to comprise a coherent program and at least one must be at or above the 300 level. Possible fields include chemistry, economics, engineering, mechanics, physics, psychology, and social relations. All courses used to meet departmental requirements must be passed with a grade of C or better.

The acquisition of at least a reading knowledge of French, German, or Russian is most strongly recommended. Students preparing for graduate work in the mathematical sciences should be aware that competence in one or two of these languages is an almost universal requirement for a graduate degree.

For information on the combined bachelor's/master's degree program, see Graduate Programs.

Mathematical Engineering

The major in Mathematical Engineering is a concentrated program designed for the student with an appetite for applied mathematics and a deep curiosity about science. This major is suitable preparation for a career in modern engineering and can also lead to graduate work in a variety of fields. It features an early and intensive exposure to basic mathematical methods which then are applied in the study of the fundamental sciences. An area of concentration is chosen so that course work toward the end of the program can focus on a field of interest to the student. The major leads to the B.E.S. or B.A. degree depending on the student's choice of electives. The courses specified for this major satisfy many of the requirements for the combined bachelor's-master's program in mathematical sciences; mathematical engineering majors should therefore consider enrollment in this program as well.

Information about admission to the major and a detailed program outline are available in the department office. It is essential that prospective majors begin this program in their first semester.

Graduate Programs

A wide variety of advanced courses, seminars, and research opportunities are available in the Department of Mathematical Sciences. Students who wish to pursue graduate degree programs in the traditional areas of applied mathematics, computing, operations research, probability, and statistics as well as other areas of the mathematical sciences can do so in this department.

Close cooperation with the departments of Biostatistics, Electrical Engineering, Geography and Environmental Engineering, Mathematics, Political Economy, Public Health Administration, and others further widens the opportunities available to graduate students. Joint appointments of faculty, joint development and scheduling of courses, joint work on research projects, and dissertation research in special areas under the supervision of faculty in these departments are all routine practices. The result is that a graduate student in the Department of Mathematical Sciences can develop a program in pure or applied aspects of the mathematical sciences that suits his or her abilities and objectives.

"Mathematical science" is not, per se, an independent professional discipline ı writing to the Chairman for the

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available in the department office, but a student with different goals is free to propose an appropriate program meeting the approval of the research adviser.

Elective Courses Two one-year graduate courses in fields distinct from the student's specialized area are required. Typical courses in other departments are computer engineering, econometrics, health systems, mathematics, mathematical ecology, mathematical economics, physics, psychometrics, systems theory, and urban studies. The student can construct a minor by choosing both courses in the same area, though a formal minor is not required. At least one course should be completed before the student takes the Graduate Board Examination.

Each student will develop with the adviser a complete program of proposed course work. This program should not be thought of as a firm contract but as a basis for planning; it may need to be updated and revised from time to time.

In addition to fulfilling the University requirement of a minimum of two consecutive semesters of registration as a full-time resident graduate student, the following must be completed to obtain departmental certification for the Ph.D.: (a) pass examinations focused on the material of the basic courses and the specialized courses; pass the University Graduate Board Examination; (b) complete satisfactorily the two elective courses; (c) demonstrate the ability to read scientific material in French, German, or Russian; (d) acquire some teaching experience under the supervision of the faculty; (e) demonstrate a working knowledge of the utilization of computers in the mathematical sciences; (f) complete a program of original research leading to a dissertation worthy of publication.

Facilities

The department maintains a small reference collection of books and journals in its Commons Room. Office space in Maryland Hall is offered to all resident graduate students. The facilities of the University Computing Center are available to students for research and instruction, and liberal access to terminals for time-shared computing is provided.

Fellowships and Assistantships

Teaching assistantships offering tuition fellowships and stipends at competitive levels are available to qualified graduate students. Research assistantships funded by grants and contracts from business and governmental agencies are sometimes available to advanced graduate students engaged in their dissertation research.

COURSES

Prospective students are invited to discuss with individual instructors the aims and prerequisites of their courses; formal prerequisites are listed only to indicate the level of proficiency expected and can be waived by the instructor for sufficient cause.

Applied Mathematics

24.301(Q) Matrix Analysis and Linear Algebra
A second course in linear algebra with emphasis on those parts of the subject which are

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useful in analysis, economics, statistics, control theory, and numerical analysis. Topics include: review of linear algebra, decomposition and factorization theorems, positive definite matrices, norms and convergence, eigenvalue location theorems, variational methods, positive and non-negative matrices, generalized inverses. Prerequisite: linear algebra and advanced calculus (11.12-13 or equivalent). Corequisite: 11.305. Offered fall term.
4 credits

24.302(Q) Modern Algebra for Applications
Introduction to finite mathematics. Sets, relations, functions, graphs, groups, Boolean algebras, rings, fields, and lattices; selected applications to modern practical problems in digital computers and data communications. Prerequisite: 11.6-7, or 11.8-9, or the equivalent. Corequisite: 11.11 or 11.13 or equivalent. Offered spring term.
3 credits

24.307(Q) Introduction to the Theory of Games
The elements of two-player zero-sum game theory are presented along with selected applications to military and athletic competition. Infinite games and dueling, simple multi-stage games, and an introduction to the many-player theories are discussed. Prerequisite: 11.12-13 or equivalent. Offered fall term 1975-76.
3 credits

24.309(Q) Problems in Applied Mathematics
Selected topics in applied mathematics drawn from the instructor's industrial and government experience. Prerequisite: calculus and linear algebra. Offered spring term.
2 credits

24.349(Q) Combinatorial Analysis
Counting techniques: generating functions, recurrence relations, Polya's theorem. Combinatorial designs: Latin squares, finite geometries, balanced incomplete block designs. Emphasis is on problem solving. Together with 24.350, this constitutes an introduction to discrete mathematics. Prerequisite: Linear algebra and advanced calculus. Offered fall term.
3 credits

24.350 Graph Theory
Connectivity, Euler and Hamiltonian tours, matching, symmetry, extremal problems, planarity, coloring, the Four Color Problem. Attention is directed toward problem solving, algorithms, and applications. Together with 24.349 this constitutes an introduction to discrete mathematics. Prerequisite: Linear algebra and advanced calculus. Offered spring term.
3 credits

24.355-356(E,Q) Differential Games
A theory and means of solving problems of conflict in which the two players continuously make decisions to obtain contrary objectives. Control theory is the special case of one-player differential games. But the full theory is more than a mere formal generalization, for the fact that each player must take into account the actions of his opponent makes the two-player case deeper and richer. Applications include pursuit and evasion, control problems with nature as antagonist, military strategy. Prerequisite: A working knowledge of ordinary differential equations and the mathematical maturity of a course in advanced calculus. Not offered 1975-76.
3 credits

Graduate (600 level)

24.608 Many-Player Games
This course presents a number of the more successful theories of multi-player games, including the original von Neumann-Morgenstern theory, the theory of the core, and that of the Shapley value. Games with and without side-payments are considered, as are non-cooperative games and their Nash equilibrium solutions. Application to economic decisions are stressed. Prerequisite: 24.307. Offered spring term 1975-76.
3 hours weekly

Computing and Numerical Analysis

24.1(Q) Computer Laboratory; Calculus I
The basic concepts, principles and theorems of the calculus are illuminated with computational exercises to be solved using a timeshared computer. The problems assigned parallel the topics treated in 11.6 and 11.8. No previous programming or computing experience is required. Corequisite: Concurrent registration in 11.6 or 11.8. Offered both terms.
1 credit

24.2(Q) Computer Laboratory: Calculus II
The basic concepts, principles and theorems of the calculus are illuminated with computational exercises to be solved using a timeshared computer. The problems assigned parallel

, control theory, and numerical analysis. Topics in-
position and factorization theorems, positive definite
nvalue location theorems, variational methods, posi-
zed inverses. Prerequisite: linear algebra and advanced
equisite: 11.305. Offered fall term.

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sets, relations, functions, graphs, groups, Boolean
ected applications to modern practical problems in
tions. Prerequisite: 11.6-7, or 11.8-9, or the equiva-
valent. Offered spring term.

Games
game theory are presented along with selected appli-
ition. Infinite games and dueling, simple multi-stage
y-player theories are discussed. Prerequisite: 11.12-13

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the topics treated in 11.7 and 11.9. No previous programming or computing experience is required. Corequisite: Concurrent registration in 11.7 or 11.9. Offered both terms.
1 credit

24.62(E,Q) Elements of Computer Art and Science
This course is designed to provide a basic knowledge of digital computers for those who intend to go on in the field, and a fundamental understanding of the use of computers in modern society for those who will do no further work in the field. Topics include use of computer libraries, reading and writing computer programs, analysis of algorithms, managerial and scientific applications, simulation, and artificial intelligence. In the laboratory period, students use remote time-sharing and batch-processing. The course is intended for those with no previous experience with computers. Although the only prerequisite is high school mathematics, students without some additional mathematics are likely to find the course difficult. Prerequisite: Four years of high school mathematics. Offered both terms.
3 credits

24.63(Q) Computer Programming Workshop
This course is intended to give practice and guidance in the application of fundamental computer programming techniques. A moderately difficult project will be proposed, analyzed, programmed, debugged, critiqued, refined for efficiency, and documented. Structuring of tasks, interfacing, programming style, efficiency profiling, test case preparation and documentation will be discussed with examples provided by the project. Prerequisite: 24.62 or equivalent. Offered fall term.
3 credits

24.319(E,Q,S) Systems Modeling
Computer modeling of social and economic systems from the viewpoint of the engineer. Scenario analysis. System dynamics. Applications to world growth, urban decay, national economic policy, commodity prices, market behavior, and resource depletion. Computer laboratory. Prerequisite: 24.62, 11.12 or equivalent. Knowledge of difference and differential equations desirable. Offered fall term.
4 credits

24.320(Q,S) Econometric Modeling
Computer modeling of social and economic systems from the viewpoint of the economist. Multiple linear regression, multicollinearity, autoregression, distributed lags, generalized least squares, simultaneous-equation models, identification, estimation procedures, forecasting, and simulation. Computer laboratory. Prerequisite: 24.62, 24.332 or consent of instructor. Offered spring term.
4 credits

24.362(E,Q) Principles of Computer Algorithms and Models
Algorithms, structure of programs, lists, trees, sorting, searching, hash coding, random number generation, Monte Carlo simulation, simultaneous-equation models, heuristic programming, systems programming. Computer laboratory. Prerequisite: 11.12, 24.62 and 24.315. Offered spring term.
4 credits

24.365-366(Q) Numerical Analysis
Fall term: Computational linear algebra with emphasis on matrix computations and careful implementation of algorithms. Spring term: General tools and techniques for the numerical solution of mathematical problems and the analysis of solution algorithms. Topics: data fitting and function approximation; numerical integration and differentiation; solution of nonlinear equations and systems of equations; difference and differential equations. Prerequisite: Fall term: 24.62, 11.13, and 11.305 or equivalent; spring term: 24.365.
4 credits

Mathematical Programming—Optimization

24.303(Q) Foundations of Optimization
A study of the basic principles underlying optimization. Topics include unconstrained optimization, constrained optimization, saddlepoint conditions, Kuhn-Tucker and Fritz John conditions, linear programming, the simplex algorithm, post-optimality, duality, quadratic programming. Prerequisite: 11.13 or equivalent. Corequisite: 11.305. Concurrent registration in 24.301 is recommended. Offered fall term.
4 credits

24.345-346(E,Q) Introduction to Mathematical Programming
A survey course in optimization methods and applications at an elementary level. A wide variety of optimization techniques is studied including linear programming, graph theory, search techniques, dynamic programming, integer programming, and nonlinear programming

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(classical optimization and Kuhn-Tucker theory). Appropriate for undergraduate and graduate students without the mathematical background required for 24.303. Students who may wish to pursue further work in optimization should consider 24.303. Prerequisite: 11.6-7 and 24.62 or equivalent. Corequisite: concurrent registration in 11.12-13 or 11.11-12.
3 credits

24.609 Advanced Linear Programming
Topics in the theory and application of maximizing a linear function subject to linear constraints including the dual simplex, primal-dual and other algorithms; transportation problems; the decomposition principle; and upper bounding. Prerequisite: 24.303 or consent of instructor. Offered spring term.
2 hours weekly

24.610 Nonlinear Programming
Algorithms for the solution of nonlinear optimization problems are developed. Topics include quadratic programming, convex programming, decomposition algorithms, gradient methods, second-order methods, and geometric programming. Prerequisite: 24.303. Offered spring term.
2 hours weekly

24.613 Dynamic Programming
A study of the optimization of sequential or multistage decision processes based upon the application of the dynamic programming principle of optimality. Both computational and theoretical aspects will be explored. Not offered 1975-76.
3 hours weekly

24.614 Theory of Optimization
The primary objective of this course is to demonstrate that much of optimization theory can be unified effectively by a few geometric principles. Problems of the calculus of variations, optimal control, mathematical programming, approximation, and prediction will be discussed. Prerequisite: 24.303 or permission of instructor. Offered spring term. Not offered 1975-76.
2 hours weekly

24.685-686 Combinatorial Optimization
Algorithms and min-max theorems for problems in combinatorial optimization. First term: Network flow theory, including maximum flow, minimum cost flow, the scaling algorithm, out-of-kilter algorithm. Dynamic flows and other extensions. Optimal bipartite matching. Second term: Optimal matching for general graphs, the Chinese postman. Travelling salesman and other "hard" problems. Matroid partition, intersection, and connectivity. Graph planarity, connectivity, and isomorphism. Prerequisite: Knowledge of linear programming and consent of instructor. Not offered 1975-76.
3 hours weekly

24.687 Integer Programming
Algorithms for linear programs in which some of the variables are restricted to integer values. Enumerative methods, cutting plane methods, Benders' partitioning algorithm, group theoretic methods. Prerequisite: Knowledge of linear programming and consent of instructor. Offered fall term.
3 hours weekly

24.689-690 Large Scale Programming
Techniques for solving large mathematical programming problems, including exploitation of the special structure of certain classes of problems. Topics include: column generation, decomposition principle, generalized programming, partitioning. Prerequisite: 24.609, 24.610.
2 hours weekly

Operations Research

24.351-352(E,Q) Inventory Systems
The art of building and analyzing models as applied to inventory systems. Theoretical and quantitative approach to problems of balancing carrying costs, shortage costs, and replenishing costs. Optimal decision rules pertaining to "when to replenish" and "by how much." Deterministic and probabilistic demand, zero and non-zero leadtime, price discounts, multi-item systems, equivalence of systems, choice of optimal policies, heuristic decisions. Application of sensitivity analysis, simulation, mathematical programming, Markov chains, and computers. Prerequisite: 24.62, 24.315 or equivalent.
3 credits

24.353(E,Q,S) Foundations of Management Science I
The organizational environment in which the methodologies of management science are applied. Consideration is given to organization structure and behavior and to the tech-

n-Tucker theory). Appropriate for undergraduate and
:hematical background required for 24.303. Students who
k in optimization should consider 24.303. Prerequisite:
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nologies of operations and systems. Emphasis is placed on the development of models of purposeful systems. Prerequisite: 24.11-12 or equivalent. Offered fall term.
3 credits

24.354(E,Q) Foundations of Management Science II
Quantitative methodologies of operations research and their applications. Topics include linear, integer, and dynamic programming; inventory, queueing, and game systems; the use of optimization, simulation, and computer techniques. Computer laboratory. Prerequisite: 24.62, 24.315. Offered spring term.
3 credits

24.359(E,Q) Game Systems
Introduction to the theory of games and to artificial intelligence. Games played by machines. Heuristic programming. Parlor games, business games, and other decision games. Evaluation functions. Efficient notations and recording schemes. Teaching a machine to learn. Look ahead, tree searching, and branch and bound. The computer as a consultant. Prerequisite: 24.62, 24.315 or equivalent. Not offered 1975-76.
3 credits

24.647-648 Seminar in Policy Analysis
Policy-relevant modeling efforts and technology assessments in one or more problem areas such as energy, food, monetary control, land use, housing, poverty, pollution, and economic growth.
2 hours weekly

Probability and Statistics

24.11-12(Q) Statistical Analysis
An introduction to the concepts of probability and statistics and a general survey of useful statistical methodology. Time-shared computing is used to gain experience with (simulated) random phenomena, to perform tedious calculations useful in demonstrating concepts, and to perform statistical analyses of data. No previous experience in computing is required. Topics include: Fall term: Probability; random variables; sampling and handling sample data; introduction to statistical decision theory; basic ideas of classical estimation and testing. Spring term: Inference for one population (including nonparametric methods); comparing two populations (including nonparametric methods); multinominal data; regression (linear, polynomial, multiple); correlation; the analysis of variance. The first term is intended to introduce the basic ideas used by statisticians and to provide a basis for the second term, which uses these ideas to develop specific methodology. The course covers the most common ideas and methods which occur in the literature of economics, psychology, sociology, and other areas of empirical research. This is a general survey course which is directed toward potential users of statistical ideas and methodology; students who may wish to pursue further work in probability or statistics or who wish to delve more deeply into the theory of these subjects should elect 24.315-316 or 24.321-324. Calculus is not a prerequisite to this course; students who have studied a year of calculus should consider 24.315-316. Prerequisite: Four years of high school mathematics.
4 credits

24.315(Q) Introduction to Probability
Probability models, random variables, distributions, stochastic independence, conditional probability. Emphasis is placed on applications of probability theory to other scientific disciplines rather than on rigorous demonstrations of mathematical results. This course can be followed by further work in statistics (24.316), regression (24.332), or stochastic processes (24.317). However, students who may wish to pursue graduate work in probability, stochastic processes, or statistics should consider 24.321. A year of calculus is an essential prerequisite to this course. Prerequisite: 11.6-7 or 11.8-9 or the equivalent. Offered fall term.
4 credits

24.316(Q) Introduction to Statistics
Principles of statistical reasoning. Application of statistical inference to a variety of problems in the physical, biological and behavioral sciences; data analysis. Prerequisite: 24.315 or consent of instructor. Offered spring term.
4 credits

24.317-18(Q) Stochastic Systems
Studies of the behavior of stochastic systems. The course begins with a review of analytic techniques and a study of stochastic processes sufficient to understand queueing phenomena. Compound distributions, solution of differential-difference equations by means of generating functions, discrete and continuous time Markov processes, time-homogeneous

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immigration-emigration, and birth-death processes are among the topics considered. Stochastic systems such as single and multiple channel queues, Erlang systems, interference systems, priority queues, and sequential queues are then examined for their unique characteristics and with an orientation toward application to real-world problems. Prerequisite: 24.315-316 or consent of instructor.
3 credits

24.321(Q) Introduction to Probability Theory
An introduction to probability theory as a mathematical discipline. Probability spaces, combinatorial probability, random variables, expectation, independence, transforms, convergence. Important probability distributions. Limit theorems for sums of independent random variables. Emphasis on establishment of mathematical results rather than applications of probability processes to other fields. Provides a foundation for further study in probability, stochastic processes, or statistics. Prerequisite: 11.12-13 or equivalent. Corequisite: 11.305 or equivalent. Offered fall term.
4 credits

24.322(Q) Introduction to Stochastic Processes
Theory of Poisson processes, Markov chains, Markov processes, and renewal processes; applications illustrative of important mathematical principles. Treatment of dependence, structural properties, sample path behavior and limit theorems. Development of mathematical results is emphasized and facility with basic techniques of analysis is assumed. Prerequisites: 24.321 and 11.305 or equivalent. Offered spring term.
4 credits

24.324-325(Q) Introduction to Statistical Theory
An introduction to classical statistical inference and Bayesian inference. First semester (spring term): Likelihood, sufficiency, point and interval estimation; testing hypotheses, simple and composite; elements of decision theory. Emphasized theoretical results: Cramer-Rao Inequality, Rao-Blackwell Theorem, Neyman-Pearson Lemma, Gauss-Markov Theorem. Second semester (fall term): likelihood, sufficiency, and conditionality principles; Bayesian inference; elements of statistical decision theory; the fiducial argument; some finite-population sampling theory. Prerequisite: 24.321. First semester prerequisite to the second.
3 credits

24.332(Q) Least Squares and Regression Analysis
Theory and applications of least squares and multiple linear regression (and correlation). Weighted least squares, estimation of error, regression in terms of linear vector spaces, reduced and adjusted regression analysis, non-linear regression and iterative non-linear least squares estimation, introductory analyses of variance and covariance, orthogonal polynomials, random-β regression analysis. Prerequisite: 24.315-316 or 24.321-324; linear algebra or consent of instructor. Offered fall term.
3 credits

24.333(Q) Design of Experiments
Experimental design principles and applications. Theory of singular linear models: estimable functions, generalized inverses and their applications in design analyses. Completely randomized, complete block, latin square, factorial and balanced and partially balanced incomplete block designs. Multiple comparisons. Confounding, fractional replications, transformations, and the analysis of covariance. Random effects, mixed models and variance components analyses. Prerequisite: 24.332. Offered spring term.
3 credits

24.334(Q) Statistical Methods
Statistical methods and their implementation are discussed. Necessary theory is considered but the emphasis of the course is on methodology. Topics include estimation and testing in one and two sample situations; contingency tables and goodness of fit; linear regression; correlation; analysis of variance. Prerequisite: 24.321 or consent of instructor. Offered spring term.
3 credits

24.336(Q) Stochastic Processes in Biology and Medicine
Deterministic growth models and stochastic model building. Branching processes in discrete and continuous time. Poisson process and its generalizations. Compound and contagious distributions. Birth-death and jump processes. Renewal and stationary point processes with biological applications. Epidemics and rumors. Diffusion processes. Statistical inference for selected processes. Prerequisite: 24.321-322. Offered spring term.
3 credits

24.338(Q) Sampling and Survey Methods
Theory and application of sampling finite populations. Design of surveys; simple random,

leath processes are among the topics considered. Sto-
multiple channel queues, Erlang systems, interference
itial queues are then examined for their unique charac-
ward application to real-world problems. Prerequisite:

/ Theory

ory as a mathematical discipline. Probability spaces,
variables, expectation, independence, transforms, con-
ributions. Limit theorems for sums of independent ran-
hment of mathematical results rather than applications
vides a foundation for further study in probability,
erequisite: 11.12-13 or equivalent. Corequisite: 11.305

Processes

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t mathematical principles. Treatment of dependence,
ehavior and limit theorems. Development of mathe-
acility with basic techniques of analysis is assumed,
uivalent. Offered spring term.

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cal inference and Bayesian inference. First semester
y, point and interval estimation; testing hypotheses,
cision theory. Emphasized theoretical results: Cramer-
em, Neyman-Pearson Lemma, Gauss-Markov Theorem,
od, sufficiency, and conditionality principles; Bayesian
sion theory; the fiducial argument; some finite-popula-
321. First semester prerequisite to the second.

n Analysis

ares and multiple linear regression (and correlation),
f error, regression in terms of linear vector spaces,
alysis, non-linear regression and iterative non-linear
y analyses of variance and covariance, orthogonal
alysis. Prerequisite: 24.315-316 or 24.321-324; linear
d fall term.

plications. Theory of singular linear models: estimable
their applications in design analyses. Completely
uare, factorial and balanced and partially balanced
mparisons. Confounding, fractional replications, trans-
riance. Random effects, mixed models and variance
32. Offered spring term.

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methodology. Topics include estimation and testing
tingency tables and goodness of fit; linear regression;
requisite: 24.321 or consent of instructor. Offered

gy and Medicine

astic model building. Branching processes in discrete
and its generalizations. Compound and contagious
ocesses. Renewal and stationary point processes with
rumors. Diffusion processes. Statistical inference for
322. Offered spring term.

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nite populations. Design of surveys; simple random,

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stratified, and systematic samples; ratio and regression estimates; subsampling; cost factors and sources of error; superpopulation models. Prerequisite: 24.315-316 or 24.321-324; 24.332. Offered fall term.

3 credits

24.601-602 Analysis and Probability

A rigorous and thorough treatment of modern probability theory. First semester: Measure and integration theory. Convergence theorems, L^p spaces, the Radon-Nikodym theorem, Fubini's theorem, Lebesgue measure, the Kolmogorov extension theorem. Introduction to functional analysis. Second semester: Measure theoretic probability, independence, conditioning, characteristic functions. Discrete time martingales with applications. Classical limit theorems in full generality. Infinite divisibility. An elementary course in probability is suggested, but not essential, as background. Prerequisites: first term: 11.305 or equivalent; second term: 24.601 and 11.381 or equivalent.

4 hours weekly

24.651-652 Statistical Inference

Advanced theory of statistical inference. First semester: General decision theory and its connections with game theory; completeness and sufficiency; unbiased tests; invariant tests; robustness; sequential analysis, sequential choice of experiments, stopping rules. Second semester: Large-sample theory; maximum-likelihood estimates, likelihood-ratio tests, chi-squared tests, minimum chi-squared estimates, asymptotic relative efficiency, contingency tables and information theory, estimation of density functions. Prerequisite: 24.601-602 (may be taken concurrently with approval of instructor).

4 hours weekly

24.653 Large Sample Statistical Theory

Statistical theory in the asymptotic case. Topics include: types of convergence of sequences of random variables; generalizations of basic probability limit theorems; sample statistics, functions of sample statistics and their properties; U-statistics; asymptotic theory in parametric inference; Bahadur and Pittman efficiencies. Prerequisite: 24.601-602, 24.324.

3 hours weekly

24.654 Multivariate Statistical Theory

Theory of statistics when data are in the form of multivariate observations. Topics include: the multivariate normal distribution; estimation of mean and covariance matrices; distribution of sample correlation coefficients; Hotelling's T^2-statistic and its uses; discrimination; Wishart distribution; multivariate analysis of variance; principal component analysis. Prerequisite: 24.324. Offered fall 1976-77.

3 hours weekly

24.655 Time Series Analysis

Time series analysis from both the frequency and time domain approach. Topics include: The spectrum and its sample estimates; smoothing a spectral estimate; designing an experiment for the collection of time series data; interpretation of the analysis; cross-spectral analysis. The general mixed autoregressive-moving average model; model estimation and prediction; model diagnostic checking. Prerequisite: 24.324. Offered spring term 1976-77.

3 hours weekly

24.656 Linear Statistical Models

Statistical theory of models which are linear functions of the parameters. Topics include: the principle of least squares; estimability and the generalized Gauss-Markov theorem; canonical form of the linear model; conditional and generalized inverses; projections, projection operators, idempotent matrices, error and estimation spaces; Cochran's theorem and its equivalent forms; extensions of the Gauss-Markov theorem to general error covariance structures; estimation and tests of hypotheses, parametrically partitioned models; augmentation and deletion of parameters. Prerequisite: 24.301, 24.324. Offered spring 1976-77.

3 hours weekly

24.657 Nonparametric and Robust Statistical Inference

Topics include: order statistics; run tests; goodness of fit tests; general one and two sample problems; asymptotic relative efficiency; linear rank statistics and applications to location and scale problems; robust estimates of location; robust estimates of scale; jackknifing; measures of association; regression and the analysis of variance. Prerequisite: 24.324. Offered fall 1975-76.

3 hours weekly

24.658 Reliability Theory

Estimation of reliability of components and systems; point estimates and interval estimates; failure data by attributes and by variables; models for systems in series, parallel, and

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mixed; extremal distribution; IFR and IFRA distributions; optimal design, inspection, repair, and replacement of systems. Prerequisite: 24.324.
3 hours weekly

24.659 Sequential Analysis
Wald's sequential probability ratio test; operating characteristics, sample size, and optimal properties; fundamental identity of sequential analysis; Bayes and minimax sequential decision rules; invariant sequential decision problems; sequential estimation; sequential design of experiments. Prerequisite: 24.324.
3 hours weekly

24.661 Stochastic Processes in Continuous Time
Theory of stochastic processes: measurability, separability, sample path properties. Brownian motion and diffusion processes. Continuous time martingales. Markov processes. Prerequisite: 24.601-602 and 24.322 or equivalent.
3 hours weekly

Potpourri

24.99(Q) Independent Study in Mathematical Sciences
Reading, research, or project work for undergraduate students as arranged individually between student and faculty. Offered both terms.

24.395(Q) Special Topics in the Mathematical Sciences
Special topics selected by the faculty for formal coursework according to the needs and interests of students in residence.

24.600 Mathematical Sciences Department Seminar
A variety of topics discussed by speakers from within and without the University. Required of all resident department graduate students. Offered both terms.
1 hour weekly

24.695 Special Topics in the Mathematical Sciences
Special topics selected by the faculty for formal coursework according to the needs and interests of students in residence.

24.699 Special Studies and Research
Reading, research, or project work for graduate students as arranged individually between student and faculty. Offered both terms.

Mathematics

The Department of Mathematics offers opportunities to students who are interested in mathematics, whether as a future career or as an adjunct to other fields. A very broad selection of courses at various levels is maintained, and over thirty courses are offered each term by a faculty of international distinction.

A great flexibility of programs is a departmental tradition, and able students are encouraged to move ahead as swiftly as possible. Students in the junior and senior years frequently take graduate-level mathematics courses, and serious students can be admitted for graduate study while still completing requirements for the B.A. degree.

Courses through the 300 level are predominantly in the domain of analysis, several of them especially designed for students in other departments. At the graduate level, most course offerings are naturally in the areas of chief importance in our graduate program, which is run by widely known experts in analysis, algebraic geometry, algebraic number theory, and topology.

The Faculty

Professor Joseph H. Sampson (Chairman): differential geometry, global analysis, algebraic geometry.
Professor John M. Boardman: algebraic and differential topology.