Department of Mathematics

Chairperson:	Bertrand, Florian J.
Professor Emeriti:	Muwafi, Amin
Professors:	Abi-Khuzam, Faruk F.; Abu-Khuzam, Hazar M.; Khuri-Makdisi, Kamal F.; Nassif, Nabil R.; Shayya, Bassam H.
Associate Professors:	Alhakim, Abbas M.; Bertrand, Florian J.; El Khoury, Sabine S.; Raji, Wissam V.; Tlas, Tamer M.
Assistant Professors:	Andrist, Rafael; Aoun, Richard G.; Della Sala, Giuseppe; Mascot, Nicolas; Monni, Stefano; Moufawad, Sophie M.; Roy, Tristan Cyrus; Sabra, Ahmad A.; Taati, Siamak; Taghavi-Chabert, Arman
Lecturers:	Fayyad, Dolly J.; Mroue, Fatima K.; Yamani, Hossam A.
Instructors:	Ashkar, Alice N.; Bou Eid, Michella J.; Fleihan, Najwa S.; Itani-Hatab, Maha S.; Khachadourian, Zadour A.; Nassif, Rana G.; Rahhal, Lina A.; Tannous, Joumana A.

The Department of Mathematics offers programs leading to the degrees of Bachelor of Science (BS) and Bachelor of Arts (BA) in Mathematics, Applied Mathematics, and Statistics. It also offers programs leading to the degree of Master of Science (MS) in Mathematics.

Mission Statement

The Department of Mathematics subscribes to the view that "Mathematics as an expression of the Human mind reflects the active will, the contemplative reason, and the desire for aesthetic perfection." Through the different fields of Algebra, Analysis, Geometry, Number Theory, Statistics, and Applied Mathematics, the department aims to train students in quantitative reasoning, in dealing with abstraction, in enhancing their sense of formalism, in tackling mathematical problems, and in writing clear and rigorous proofs. The training will help the student acquire a sound balance between abstract generality and colorful individuality, and between the qualitative and quantitative aspects of Mathematics. It also will help the student master the theory through a clear comprehension of the theoretical aspects without losing sight of applications. Graduates of the Mathematics Department should be well placed to work in various professional areas of Education, Finance, Information Technology, or for pursuing graduate studies in Mathematics or a related area.

P) Part time

BA or BS in Mathematics

The department requires 9 credits in courses numbered 200 or above in the sciences for the BS degree, and at least 9 credits in courses numbered 200 or above in the arts (Humanities or Social Sciences) for the BA degree. In both cases, it is recommended that at least 6 of these 9 credits be in disciplines that use quantitative methods and be chosen in conjunction with the student's faculty advisor. In addition, the departmental requirements are as follows: MATH 201, MATH 210, MATH 214, MATH 219, MATH 223, MATH 227, MATH 233, MATH 241, and at least one of MATH 220 or MATH 242, and 12 more credits chosen from MATH 202 and mathematics courses numbered 213 or above. In addition, students must take CMPS 200, which is a first course in programming. Students should note that MATH 211 and MATH 212 do not count towards the major course requirements for the BS and BA in Mathematics. For pure mathematics major, MATH 211 and MATH 212 may be taken as free electives.

A transfer student who has done well in MATH 218 can count it toward the mathematics major instead of MATH 219, subject to departmental approval. In such a case, the department will usually require the student to take MATH 220.

Students wishing to pursue graduate study in mathematics are strongly urged to take MATH 220, MATH 242, and MATH 213 or MATH 215. They may also want to consider taking one or more graduate course in their senior year. Students with an interest in applied mathematics are urged to take MATH 202, MATH 220, MATH 224, MATH 251, and MATH 234, and to choose their additional courses from those that include a significant use of mathematical techniques. Students interested in high school teaching are encouraged to include MATH 202, MATH 213, MATH 251, and MATH 261 among their courses.

University General Education Requirements

The General Education requirements are 6 credits in English Communication Skills and 3 credits in Arabic Communication skills, 12 credits in the Humanities, 6 credits in Social Sciences (covered by the departmental requirements for BA), 6 credits in Natural Sciences (covered by the departmental requirements for BS), and 3 credits in Quantitative Thought (covered as a Math major).

Minor in Mathematics

A minor in mathematics requires 18 credits which include MATH 201, MATH 210, MATH 218 or MATH 219, and 9 more credits in mathematics courses numbered MATH 202, MATH 211 or above, or statistics courses numbered STAT 230 or above. *Note: A student who seeks to obtain a minor in Mathematics can elect to have a minor in pure mathematics or a minor in applied mathematics, but not both.*

BA or BS in Applied Mathematics

A student opting for the program in Applied Mathematics can earn either a BA or a BS degree. The science requirements for the BS are fulfilled by at least 2 science courses (or 6 science credits) chosen in departments in the FAS; the arts requirements for the BA are fulfilled by 2 courses (6 arts credits) chosen in departments in the FAS. The Mathematics requirement is the same for both degrees and consists of 39 credits in Mathematics courses as follows:

MATH 201, MATH 202, MATH 210, MATH 212, MATH 218 or MATH 219, MATH 223, STAT 233, MATH 251, MATH 281, at least one of MATH 224 and MATH 227, and at least 9 additional credits numbered 211 and above. These additional credits must include at least two of the following three areas:

- Analysis and Geometry: MATH 213, MATH 214, MATH 215, MATH 225, MATH 224, MATH 227
- Discrete Math and Algebra: MATH 211, MATH 220, MATH 241, MATH 242, MATH 261
- Probability and Statistics: STAT 231, STAT 234 or higher

In addition, the student must take CMPS 200, which is a first course in programming. Moreover, 9 credits must be chosen in one applied discipline or track from the following list, as detailed in the matrices of the BA and BS in Applied Mathematics:

- Computer Science
- Economics/Econometrics
- Natural Sciences
- Engineering
- Health Sciences
- Statistics

University General Education Requirements

The General Education requirements are 6 credits in English Communication Skills and 3 credits in Arabic Communication Skills, 12 credits in the Humanities, 6 credits in Social Sciences (covered by the departmental requirements for BA), 6 credits in Natural Sciences (covered by the departmental requirements for BS), and 3 credits in Quantitative Thought (covered as a Math major).

Minor in Applied Mathematics

A minor in Applied Mathematics requires 18 credits which include MATH 201, MATH 210, either MATH 218 or MATH 219, and 9 more credits in mathematics courses numbered MATH 202, MATH 211 or above, or statistics courses numbered STAT 230 or above.

BA or BS in Statistics

The department requires 9 credits in courses numbered 200 or above in the sciences for the BS degree, and at least 9 credits in courses numbered 200 or above in the arts (humanities or social sciences) for the BA degree. In both cases, it is recommended that at least 6 of these 9 credits be in disciplines that use quantitative methods and be chosen in conjunction with the student's faculty advisor. The Mathematics and Statistics requirements are the same for both degrees and consist of 39 credits as follows:

- **In statistics:** STAT 231, STAT 233, STAT 234, STAT 235, STAT 236, STAT 237 and STAT 238, and 9 more credits chosen from MATH 202 and from mathematics, statistics, and computer science courses numbered 211 or above, excluding STAT 230
- **In mathematics:** MATH 201, MATH 210, and MATH 218 or MATH 219
- **In computer science:** CMPS 200.

Students planning to pursue higher education in statistics are advised to take their electives in advanced mathematics courses, such as MATH 223 and MATH 227. Other students are encouraged to choose among their electives MATH 251 and other computing-oriented courses.

It is to be noted that STAT 201, STAT 210, and STAT 230 are mainly service courses. STAT 201 is essentially equivalent to EDUC 227, and STAT 210 is essentially equivalent to ECON 213. Students can get credit for only one of the following: STAT 201, STAT 210, STAT 230, STAT 233, EDUC 227, ECON 213.

University General Education Requirements

The General Education requirements are 6 credits in English Communication Skills and 3 credits in Arabic Communication Skills, 12 credits in the Humanities, 6 credits in Social Sciences (covered by the departmental requirements for BA), 6 credits in Natural Sciences (covered by the departmental requirements for BS), and 3 credits in Quantitative Thought (covered as a Math major).

Minor in Statistics

A minor in statistics can be pursued via one of two options:

- Option 1: MATH 201, MATH 218 or MATH 219, STAT 231 , STAT 233, STAT 234 and STAT 235.
- Option 2: MATH 201, MATH 218 or MATH 219, STAT 230, STAT 234, STAT 235 and one additional advanced course in statistical sciences to be selected with the approval of the department chair. A list of recommended courses includes: STAT 236 or above, EPHD 320, EPHD 321, EECE 603, EECE 641, EECE 644, EECE 667, EECE 693, INDE 303, and INDE 430.

Course Descriptions

Mathematics

MATH 101   Calculus and Analytic Geometry I   3.1; 3 cr.
Limits, continuity, differentiation with application to curve plotting; Rolle's theorem; integration with application to area, distance, volume, arc-length; fundamental theorem of calculus, transcendental functions. *MATH 101 may be taken for credit after a student has passed MATH 203. MATH 203 may not be taken for credit after a student has passed MATH 101. Every term.*

MATH 102   Calculus and Analytic Geometry II   3.1; 3 cr.
Techniques of integration, improper integrals, polar coordinates, conic sections, analytic geometry in space, parametric equations, and vector functions and their derivatives. *Prerequisite: MATH 101. Every term.*

MATH 201   Calculus and Analytic Geometry III   3.1; 3 cr.
Sequences and series, Taylor approximation, Multivariable functions, partial derivatives, multiple integrals, cylindrical and spherical coordinates, and integration along curves. *Prerequisite: MATH 102. Every term.*

MATH 202   Differential Equations   3.1; 3 cr.
Integration of vector fields along curves and on surfaces, Green's theorem, Stokes's theorem, divergence theorem; first-order differential equations, linear differential equations, series solutions, Bessel's and Legendre's functions, the Laplace transform, and systems of differential equations. *Prerequisite: MATH 201. Every term.*

MATH 203   Mathematics for Social Sciences I   3.0; 3 cr.
Polynomials, factoring, first- and second-degree equations, inequalities, absolute value, straight lines, Gaussian elimination, functions, graphs, exponential and logarithmic functions, and differentiation. *Not open to students with prior credit in MATH 101 (or its equivalent) or MATH 201. MATH 101 may be taken for credit after a student has passed MATH 203. MATH 203 may not be taken for credit after a student has passed MATH 101. Every term.*

MATH 204   Mathematics for Social Sciences II   3.0; 3 cr.
Matrix operations, inverses, determinants, set operations, permutations, combinations, probability, rate of change, techniques of integration, differential equations, graphs of multivariate functions, partial derivatives, and optimization. *Prerequisite: MATH 101 or MATH 203. Not open to students major-ing in economics. Every term.*

MATH 210   Introduction to Analysis   3.0; 3 cr.
The real numbers, completeness, sequences, some basic topology of the real line, compact sets, Heine-Borel theorem, continuous functions, intermediate value theorem, uniform continuity, extreme values, differentiation, mean-value theorem, Taylor's theorem, Riemann integration, sequences and series of functions. *Prerequisite: MATH 201. Every term.*

MATH 211   Discrete Mathematics   3.1; 3 cr.
Logical reasoning, sets, relations and functions; mathematical induction, counting, and simple finite probability theory; analysis of algorithms, complexity; recurrence relations and difference equations; truth tables and switching circuits; graphs and trees; strings and languages. *MATH 211 does not count towards the major course requirements in pure mathematics. Pure mathematics majors may take MATH 211 as a general elective. This course is equivalent to CMPS 211. Every term.*

MATH 212   Introductory Partial Differential Equations   3.0, 3 cr.
Partial differential equations as mathematical models in science. Method of characteristics and first-order quasilinear PDEs. Transport and wave equations, D'Alembert formula. Linear evolution equation and their eigensolutions. Fourier series: pointwise convergence, Gibbs phenomena, uniform convergence of sequences and series of functions and of Fourier series, Parseval formula. Application of Fourier series in solving second and higher-order linear PDEs on bounded domains (Heat systems, Laplace and wave equations). Method of separation of variables and Sturm-Liouville systems. Energy methods to study uniqueness, and equilibrium solutions. Fourier transform, inversion formula, and application to solving partial differential equations. *MATH 212 does not count towards the major course requirements in pure mathematics. Pure mathematics majors may take MATH 212 as a general elective. Prerequisites: MATH 202. Every term.*

MATH 213   Higher Geometry   3.0; 3 cr.
Topics chosen from isometries of Euclidean space, inversion, elements of differential geometry, the Frenet frame, curvature, torsion, the pseudo-sphere, hyperbolic geometry, and affine and projective geometry. *Biennially.*

MATH 214   Topology I   3.0; 3 cr.
Topological spaces, continuous functions, separation axioms, compactness, connectedness, metrizable spaces, product spaces, quotient topology. *Prerequisite: MATH 210. Annually.*

MATH 215   Introduction to Differential Geometry   3.0; 3 cr.
Parameterized curves and the Frenet-Serret frame, fundamental theorem for curves, isoperimetric inequality, regular surfaces, Gauss map and the fundamental forms, curvature, geodesics and parallel transport, Gauss-Bonnet theorem. *Prerequisites: MATH 201 and MATH 218/219, or consent of instructor. Biennially.*

MATH 216   Topology II   3.0; 3 cr.
A senior level course covering more advanced topics in topology. *Prerequisite: Consent of instructor. Occasionally.*

MATH 218   Elementary Linear Algebra with Applications   3.0; 3 cr.
An introduction to linear algebra at a less theoretical level than MATH 219. Systems of linear equations and Gaussian elimination, vectors in R^n, matrices, determinants, vector spaces, subspaces and dimension, orthogonal projection and least-squares approximation, eigenvalues, eigenvectors, and selected applications. *Students cannot receive credit for both MATH 219 and MATH 218. Every term.*

MATH 219   Linear Algebra I   3.0; 3 cr.
A rigorous introduction to linear algebra, with emphasis on proof and conceptual reasoning. Vector spaces, linear transformations and their matrix representation, linear independence, bases and dimension, rank-nullity, systems of linear equations, brief discussion of inner products, projections, orthonormal bases, change of basis, determinants, eigenvalues, eigenvectors, and spectral theorem. *Students cannot receive credit for both MATH 219 and MATH 218. Every term.*

MATH 220   Linear Algebra II   3.0; 3 cr.
A deeper study of determinants, inner product spaces, and eigenvalue theory. Adjoints and the spectral theorem, primary decomposition, quotient spaces, diagonalization, triangularization, rational and Jordan forms, connection with modules over a PID, dual spaces, bilinear forms, and tensors. *Prerequisite: MATH 241 or consent of instructor. Annually.*

MATH 223   Advanced Calculus   3.0; 3 cr.
Metric spaces, normed vector spaces, the derivative as a linear transformation, chain rule, vector versions of mean-value theorem, Taylor's formula, inverse and implicit function theorems, Riemann integration in R^n, differential forms, the general Stokes's theorem, and notions of differential geometry. *Prerequisites: MATH 210 or MATH 224, and MATH 218 or MATH 219. Annually.*

MATH 224   Fourier Analysis and Applications   3.0; 3 cr.
Fourier series, applications of Fourier series to the heat and wave equations, the Fourier transform on Rn, applications of the Fourier transform to the wave and heat equations on Rn, Shannon's sampling formula, the Radon transform, applications of the Radon transform to medical imaging, and the discrete (or fast) Fourier transform. *Prerequisites: MATH 210, and MATH 218 or MATH 219. Annually.*

MATH 225   Wavelets and Applications   3.0; 3 cr.
Discrete Fourier Transform, Fast Fourier Transform, Wavelets on the Integers, Applications to Signal and Image Processing. *Prerequisite: MATH 224. Occasionally.*

MATH 227   Introduction to Complex Analysis   3.0; 3 cr.
Complex numbers, analytic functions, integration in the complex plane, Cauchy's integral theorem, Taylor series, Laurent series, singularities, residues, and contour integration. *Prerequisites: MATH 201 and consent of instructor. Annually.*

MATH 233   Advanced Probability and Random Variables   3.0; 3 cr.
Same description as STAT 233. Annually.

MATH 234   Introduction to Statistical Inference   3.0; 3 cr.
Same description as STAT 234. Annually.

MATH 238   Applied Probability Models   3.0; 3 cr.
Same description as STAT 238. Annually.

MATH 241   Introduction to Abstract Algebra   3.0; 3 cr.
Groups, subgroups, homomorphisms, normal subgroups and quotient groups, permutation groups, orbits and stabilizers, statement of Sylow theorems, rings, ideals, homomorphisms and quotient rings , and Euclidean and principal ideal domains. *Prerequisite: MATH 219 or MATH 218 with a good understanding of proof, or consent of instructor. Annually.*

MATH 242   Topics in Algebra   3.0; 3 cr.
Topics chosen include fields and Galois theory, advanced group theory, ring theory, modules over a PID, and other topics as determined by the instructor. *Prerequisite: MATH 241. Annually.*

MATH 251   Numerical Computing   3.1; 3 cr.
Computer number representations and round-off errors; Basic techniques in numerical analysis: root finding; Gauss elimination and PLU decomposition; polynomial and spline interpolation; differentiation and integration, Richardson extrapolation; solving initial value problems for ordinary differential equations and systems of differential equations. Implementations and analysis of algorithms are stressed. Projects using MATLAB or similar tools are assigned. *Prerequisites: CMPS 200 or EECE 230 or EECE 231, and MATH 201. Prerequisite or Co-requisite: MATH 218 or MATH 219. This course is equivalent to CMPS 251. Every term.*

MATH 261   Number Theory   3.0; 3 cr.
Prime factorization, the Euclidean algorithm, congruences, quadratic reciprocity, some Diophantine equations, binary quadratic forms, and continued fractions. *Prerequisite: MATH 219 or consent of instructor. Annually.*

MATH 271   Set Theory   3.0; 3 cr.
Operations on sets and families of sets, ordered sets, transfinite induction, axiom of choice and equivalent forms, and ordinal and cardinal numbers. *Occasionally.*

MATH 281   Numerical Linear Algebra   3.0; 3 cr.
Basic Linear Algebra Subprograms (BLAS Operations of order 1, 2 and 3). Norms of vectors and matrices. Gram-Schmidt Orthogonalization. Eigenvalues and Schur's decompositions. Singular Values Singular Value decomposition and pseudo-inverse of a rectangular matrix. Gauss transforms and PLU decomposition. Cholesky decomposition for symmetric positive definite matrices. Householder transforms and QR decomposition. Application to finding solutions to least square and linear regression problems. Iterative (indirect) methods to solve linear systems of equations: Jacobi, Gauss-Seidel, successive over-relaxation. Basic algorithms for computing eigenvalues of square matrices. *This course is equivalent to CMPS 281. Prerequisites: MATH 218 or MATH 219. Prerequisite or Co-requisite: Math 251. Annually.*

MATH 293   Senior Tutorial Courses   3.0; 3 cr.
Prerequisite: Senior standing.

BA in Mathematics: 39 Credits in Mathematics

Modes of Analysis	English and Arabic (9)	Humanities (12+3)	Social Sciences (6)	Natural Sciences (6)	Quantitative Thought (27+12+3)
Lecture Courses (9+15+6+6+42)	• Required Arabic course (3) • Required English courses (usually 6 cr.): ENGL 203(3), and/or 204(3), as determined by placement.	• Required credits in the humanities: 12 credits including 6 credits from CVSP. • Humanities or social science elective (3).	• Required courses (6)	• Required electives (6)	• Required mathematics courses (27): MATH 201(3), 210(3), 214(3), 219(3), 223(3), 227(3), 233(3), 241(3), and at least one of 220(3) or 242(3). • Required mathematics electives (12): MATH 202(3), and/or mathematics courses numbered 213 and above. • Required programming course (3): CMPS 200

BS in Mathematics: 39 Credits in Mathematics

Modes of Analysis	English and Arabic (9)	Humanities (12)	Social Sciences (6)	Natural Sciences (9)	Quantitative Thought (27+12+3)
Lecture Courses (9+12+6+9+42)	• Required Arabic course (3) • Required English courses (usually 6 cr.): ENGL 203(3), 204(3), as determined by placement.	• Required credits in the humanities: 12 credits including 6 credits from CVSP.	• Required courses (6)	• Required electives (9)	• Required mathematics courses (27): MATH 201(3), 210(3), 214(3), 219(3), 223(3), 227(3), 233(3), 241(3), and at least one of 220(3) or 242(3) • Elective mathematics courses (12): MATH 202 (3), and/or courses numbered 213 and above. • Required programming course (3): CMPS 200

BA in Applied Mathematics: 39 Credits in Mathematics

English and Arabic (9)	Humanities (12)	Social Sciences (12)	Sciences (6)	Quantitative Thought (39+3)	Free Electives (9)
• Required Arabic course (3) • Required English courses (usually 6): ENGL 203(3), and/or 204(3), as determined by placement.	• Required credits in the Humanities: 12 credits including 6 credits from CVSP.	• 6 credits in Social sciences. Must include one Economics course (3): ECON 211 • 6 credits in Arts or Social sciences.	• 6 credits in sciences.	• Required Applied Mathematics courses (30): MATH 201, 202, 210, 212, 218 or 219, 223, 233, 251, 281, and at least one of 224 / 227. • Required Mathematics electives (9): MATH courses numbered 211 and above. These credits must include at least two of the following three areas: » Analysis and Geometry » Discrete Math and Algebra » Probability and Statistics • Required Computer Science course (3): CMPS 200	• Must include 9 credits chosen in one of the following concentration areas: • Computer Science: CMPS 212, 255, 256, 257, 258, 287 • Economics/Econometrics: ECON 212, 214, 215, 217, 218, 239, 243 • Engineering • Health Sciences: EPHD 203, 203A, 227, 213 or STAT 236. • Statistics: STAT 231, 234, 235, 236, 237, 238.

BS in Applied Mathematics: 39 Credits in Mathematics

English and Arabic (9)	Humanities (12)	Social Sciences (6)	Sciences (6)	Quantitative Thought (39+3)	Free Electives (15)
• Required Arabic course (3) • Required English courses (usually 6): ENGL 203(3), and/or 204(3), as determined by placement.	• Required credits in the Humanities: 12 credits including 6 credits from CVSP.	• Must include one Economics course (3): ECON 211.	• 6 credits in Sciences.	• Required Applied Mathematics courses (30): MATH 201, 202, 210, 212, 218 or 219, 223, 233, 251, 281, and at least one of 224/227. • Required Mathematics electives (9): MATH courses numbered 211 and above. These credits must include at least two of the following three areas: » Analysis and Geometry » Discrete Math and Algebra » Probability and Statistics • Required Computer Science course (3): CMPS 200	• Must include 9 credits chosen in one of the following concentration areas: • Computer Science: CMPS 212, 255, 256, 257, 258, 287 • Economics/Econometrics: ECON 212, 214, 215, 217, 218, 239, 243. • Natural Sciences: PHYS 210, 211, 212, 217, 235, 236; CHEM 201, 217, 218. • Engineering • Health Sciences EPHD 203, 203A, 227, 213 or STAT 236. • Statistics: STAT 231, 234, 235, 236, 237, 238.

Statistics

STAT 201 **Elementary Statistics for the Social Sciences** **3.0; 3 cr.**
Data organization and frequency distributions; measures of central tendency and dispersion; probability and random variables; binomial and normal distributions; estimation, and hypothesis testing. *Open only to arts students whose mathematical preparation does not allow them to take STAT 210. Students who take STAT 201 will not receive credit for STAT 210, STAT 230, or ECON 213. Every term.*

STAT 210 **Elementary Statistics for the Sciences** **3.0; 3 cr.**
Populations, samples, and sampling error; types of data, frequency distributions, and graphical displays of data; measures of central tendency and dispersion; probability and probability distributions; conditional probability, independence, Bayes' rule, and counting rules; discrete and continuous distributions, random variables, binomial, Poisson, normal, and t distributions; point and inter val estimation and hypothesis testing; Chi Squared Tests and One way Analysis of variance, linear regression and correlation. Computer packages may be used to illustrate methods. *Students who successfully finish STAT 210 will not receive credit for STAT 201, STAT 230, STAT 233, or ECON 213. Every term.*

STAT 230   **Introduction to Probability and Random Variables**   **3.0; 3 cr.**
Display of data, properties of probability, methods of enumeration, conditional probability and independent events; univariate and bivariate distributions corresponding to both discrete and continuous variables; mixture of distributions; covariance and correlation, independent random samples and the central limit theorem; basics of point and interval estimation and hypothesis testing. *Prerequisite: MATH 201. Students who successfully finish STAT 230 will not receive credit for STAT 201, STAT 210, STAT 233, or ECON 213. Every term.*

STAT 231   **Introductory Statistical Computing**   **3.0; 3 cr.**
This course introduces the principles of statistical thinking as well as the main problems of statistics with a computational emphasis and perspective. The course begins with a primer on the R statistical environment. It then proceeds to develop the main statistical ideas of sampling, inference (point and interval estimation, hypothesis testing) and concludes with simple linear regression as a first example of modeling. Methods are illustrated with R. *Annually.*

STAT 233   **Advanced Probability and Random Variables**   **3.0; 3 cr.**
Axiomatic definition of probability, random variables, univariate and multivariate probability density functions and cumulative distribution functions; expectation; moment generating function; conditional distribution; families of discrete and continuous random variables; distribution of functions of random variables; stochastic convergence and convergence of distribution functions; the law of large numbers and the central limit theorem. *Prerequisite: MATH 201. Students who successfully finish STAT 233 will not receive credit for STAT 201, STAT 210, STAT 230, or ECON 213. Annually.*

STAT 234   **Introduction to Statistical Inference**   **3.0; 3 cr.**
Sampling distribution; point and interval estimation; Neyman-Pearson theory of hypothesis testing; likelihood ratio test; sequential analysis; elementary decision theory. *Prerequisites: STAT 233, or STAT 230 with consent of instructor. Annually.*

STAT 235   **Applied Regression Analysis**   **3.0; 3 cr.**
Simple Linear Regression. Multiple Regression. Main Effects and Their Interpretation. Complex Regressors. Testing and Analysis of Variance. Weighted Least Squares. Variance Stabilizing Transfor-mations. The Delta Method. Bootstrap. Cross Validation. Regression Diagnostics. Variable Selection. Penalized Regression. Logistic Regression, Poisson Regression. *Prerequisites: MATH 218 or MATH 219; STAT 234, or STAT 230 with the consent of the instructor. Annually.*

STAT 236   **Sampling Techniques**   **3.0; 3 cr.**
Simple random, systematic, stratified, cluster, and two-stage sampling; estimation of parameters and properties of estimates; ratio and regression estimates; problem of non-response. *Prerequisite: STAT 234. Biennially.*

STAT 237   **Applied Nonparametric Methods**   **3.0; 3 cr.**
Order statistics; sign test, Wilcoxon signed-rank test, and Mann-Whitney test; run test and test for randomness; goodness of fit tests; efficiency. *Prerequisite: STAT 234 or consent of instructor. Biennially.*

STAT 238   **Applied Probability Models**   **3.0; 3 cr.**

Conditional probability and expectation; discrete and continuous time Markov chains; Chapman-Kolmogorov difference and differential equations; limiting probabilities; branching, Poisson, and birth and death processes; distribution of arrival times; queuing theory. *Prerequisites: MATH 218 or MATH 219; and STAT 233, or STAT 230 with consent of instructor. Annually.*

STAT 239   **Statistical Learning**   **3.0, 3 cr.**

This is an introductory-level course mostly in supervised statistical learning, with a focus on regression and classification methods. It will cover the following topics: Linear and polynomial regression, logistic regression and linear discriminant analysis. Resampling methods (cross-validation and the bootstrap). Model selection and regularization methods (ridge regression and lasso). Non-linear models and generalized additive models. Tree-based methods, random forests and boosting. Support-vector machines. A few unsupervised methods (principal component analysis, k-means and hierarchical clustering) will be covered as well. *Prerequisites: MATH 218 or MATH 219; and STAT 234, or STAT 230 with consent of the instructor. Annually.*

BA in Statistics: 36 Credits in Statistics/Mathematics

Modes of Analysis	English and Arabic (9)	Humanities (12+3)	Social Sciences (6)	Natural Sciences (6)	Quantitative Thought (9+21+9+3)
Lecture Courses (9+12+6+6+42)	• Required Arabic course (3) • Required English courses (usually 6 cr.): ENGL 203(3), 204(3) as determined by placement	• Required credits in the humanities: 12 credits including 6 credits from CVSP • Humanities or social science elective (3)	• Required courses (6)	• Required electives (6)	• Required mathematics courses (9): MATH 201(3), 210(3), 218 or 219(3) • Required statistics courses (21): STAT 231(3), 233(3), 234(3), 235(3), 236(3), 237(3), 238(3) • Elective MATH/STAT/CMPS (9): Courses numbered 211 and above, excluding STAT 230 • Required programming course (3): CMPS 200 (3)

BS in Statistics: 36 Credits in Statistics/Mathematics

Modes of Analysis	English and Arabic (9)	Humanities (12)	Social Sciences (6)	Natural Sciences (9)	Quantitative Thought (9+21+9+3)
Lecture Courses (9+12+6+9+42)	• Required Arabic course (3) • Required English courses (6 cr.): ENGL 203(3), 204(3), as determined by placement	• Required credits in the humanities: 12 credits including 6 credits from CVSP	• Required Courses (6)	• Required Electives (9)	• Required mathematics courses (9): MATH 201(3), 210(3), 218 or 219(3) • Required statistics courses (21): STAT 231(3), 233(3), 234(3), 235(3), 236(3), 237(3), 238(3) • Elective MATH/STAT/CMPS (9): Courses numbered 211 and above, excluding STAT 230 • Required programming course (3): CMPS 200(3)