Students must complete one 4-credit or two 2-credit math courses (BE 601-604) from the list below and pass with a B+ or higher. Students may petition for a different course (500-level or higher) to satisfy the math requirement.

ENG EC 505 Stochastic Processes An introduction to discrete and continuous-time random processes. Correlation and power spectral density functions. Linear systems driven by random processes. Optimum detection and estimation. Bayesian, Weiner and Kalman filtering.

ENG EK 501 Mathematical Methods I: Linear Algebra and Complex Analysis An introduction to basic applied mathematics for science and engineering, emphasizing practical methods and unifying geometrical concepts. Topics include linear algebra for real and complex matrices. Quadratic forms, Lagrange multipliers and elementary properties of the rotation group. Vector differential and integral calculus. Complex function theory, singularities and multi-valued functions, contour integration and series expansions. Fourier and Laplace transforms. Elementary methods for solving ordinary linear differential and systems of differential equations with applications to electrical circuits and mechanical structures.

CAS MA 561 Methods of Applied Mathematics I Derivation and analysis of the classical equations of mathematical physics; heat equation, wave equation, and potential equation. Initial boundary value problems, method of separation of variables, eigenvalue problems, eigenfunction expansions. Fourier analysis. Existence and uniqueness of solution.

CAS MA 565 Mathematical Models in the Life Sciences An introduction to mathematical modeling, using applications in the biological sciences. Mathematics includes linear difference and differential equations, and an introduction to nonlinear phenomena and qualitative methods. An elementary knowledge of differential equations and linear algebra is assumed.

CAS MA 579 Numerical Methods for Biological Sciences An introduction to the use of numerical methods for studying mathematical models of biological systems. Emphasis on the development of these methods; understanding their accuracy, performance, and stability; and their application to the study of biological systems.

CAS MA 684 Applied Multiple Regression and Multivariable Methods Application of multivariate data analytic techniques. Multiple regression and correlation, confounding and interaction, variable selection, categorical predictors and outcomes, logistic regression, factor analysis, MANOVA, discriminant analysis, regression with longitudinal data, repeated measures, ANOVA.

CAS PY 501 Mathematical Physics An introduction to complex variables and residue calculus, asymptotic methods, and conformal mapping; integral transforms; ordinary and partial differential equations; non-linear equations; integral equations.

ENG BE 567 Nonlinear Systems in Biomedical Engineering Introduction to nonlinear dynamical systems in biomedical engineering. Qualitative, analytical and computational techniques. Stability, bifurcations, oscillations, multistability, hysteresis, multiple time-scales, chaos. Introduction to experimental data analysis and control techniques. Applications discussed include population dynamics, biochemical systems, genetic circuits, neural oscillators, etc.

NOTE: **If students take courses from the BE 601-604 series they must take BE 601 and then either BE 602, BE 603, or BE 604 to satisfy the Math Requirement. Rudimentary programming skills are necessary for these modules.**

ENG BE 601 Linear Algebra The first of four math modules designed to reinforce basic mathematical and computer programming concepts pertinent to graduate research in biomedical engineering. This course will emphasize the five cornerstones of applied linear algebra: Linear combinations, decompositions, orthogonality, metric, and linear transformations. Topics include LU and QR factorizations, finite difference methods for solving partial differential equations (PDEs), least squares, Fourier series and wavelets, solid mechanics, Markov chains, principal component analysis, and signal processing techniques. This course will provide the necessary linear algebra background needed to solve problems in BE 602, 603 and 604.

ENG BE 602 Ordinary Differential Equations This math module will focus on four key ODE concepts: Linear dynamical systems, nonlinear conservative and excitable systems, discrete- time state machines, and generalized Fourier series solutions to Sturm-Liouville problems. Topics include: Filters, enzymatic networks, mechanical models for biomaterials, oscillators and limit cycles, phase- locked loops, nonlinear Leslie matrices, Legendre polynomials, Bessel functions, and a prelude to solving PDE problems associated with heat transfer, diffusion, and electrostatics. Prior exposure to linear algebra (BE 601 or equivalent), and working knowledge of a programming language (Matlab, Python, etc.) is helpful.

ENG BE 603 Partial Differential Equations This math module will focus on elliptical and parabolic PDEs associated with transport phenomenon problems in biomedical engineering. We will visit four PDE concepts: Separation of variables, integral transform solutions, superposition principles, and numerical approximations using finite-difference schemes. Topics include: 2D and 3D anisotropic Laplace's, Poisson's, and the heat equations in different coordinate systems, Fourier and Laplace transform solutions, 2D ADI methods, Green's functions, and the method of images. Prior exposure to linear algebra (BE 601 or equivalent), ODEs (BE 602 or MA 226 equivalent), Fourier series, Fourier and Laplace transforms (BE 401 equivalent), and working knowledge of a programming language (Matlab, Python, etc.) is highly recommended.

ENG BE 604 Statistics and Numerical Methods This math module will focus on how linear algebra, ODEs, statistics, and signals & systems techniques can be used to interrogate data from biological and engineering experiments. The lecture topics include: Jacobi, Gauss-Seidel, and SOR iterative solvers for large linear systems; Gauss-Newton iterations (nonlinear least-squares); the ANOVA table, multi- factor regression, and intro to the general linear model (GLM); data deconvolution; Monte Carlo, bootstrap, and kernel density estimation. Prior exposure to linear algebra (BE 601 equivalent), basic probability and statistics (BE 200 equivalent), and working knowledge of a programming language (Matlab, Python, etc.) is highly recommended.

ENG BE 747 Advanced Signals and Systems Analysis for Biomedical Engineering Introduction to advanced techniques for signals and systems analysis with applications to problems in biomedical engineering research. Time-domain and frequency-domain analysis of multiple input, multiple output systems using the fundamental matrix approach. Hilbert transform relations; applications to head- related transfer functions. Second-order characterization of stochastic processes: power density spectra, cross-spectra, auto-and cross-correlation functions. Gaussian and Poisson processes. Models of neural firing patterns. Effects of linear systems on spectra and correlation functions. Applications to models of the peripheral auditory system. Optimum processing applications. Applications to psychophysical modeling. Introduction to wavelets and wavelet transforms. Wavelet filter banks and wavelet signal processing.

ENG ME 566 Advanced Engineering Mathematics Introduces students of engineering to various mathematical techniques that are necessary in order to solve practical problems. Topics covered include a review of calculus methods, elements of probability and statistics, linear algebra, transform methods, difference and differential equations, numerical techniques, and mathematical techniques in optimization theory. Examples and case studies focus on applications to several engineering disciplines. The intended audience for this course is advanced seniors and entering MS engineering students who desire strengthening of their fundamental mathematical skills in preparation for advanced studies and research.

GRS MA 681 Accelerated Introduction to Statistical Methods for Quantitative Research Introduction to statistical methods relevant to research in the computational sciences. Core topics include probability theory, estimation theory, hypothesis testing, linear models, GLMs, and experimental design. Emphasis on developing a firm conceptual understanding of the statistical paradigm through data analyses.