MATHEMATICS AND ENGINEERING

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This plan was developed at Queen's in response to the need for engineers who possess the skills and insights of applied mathematicians. In the second and third years of the plan, half of the curriculum consists of honours courses in pure and applied mathematics; the balance consists of engineering courses in one of three sub-plans offered in cooperation with the departments of Mechanical, Electrical and Computer Engineering, and the School of Computing. The sub-plans are developed with appropriate applications of mathematics to engineering in the final year. The sub-plans are:

Options available:

- (M6) **Applied Mechanics**: (mechanics, dynamics, fluid mechanics, thermodynamics)
- (M9) **Computing and Communications**: (computer science, software design, communication, information systems, and electrical engineering)
- (M11) **Systems and Robotics**: (electrical and mechanical engineering, control, communications, information systems, robotics, and mechanics)

Programs

- Mathematics and Engineering, B.A.Sc. (Class of 2025) (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/mathematics-engineering/mathematics-engineering-basc-class-2024/)
- Mathematics and Engineering, B.A.Sc. (Class of 2026) (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/mathematics-engineering/mathematics-engineering-basc-class-2026/)
- Mathematics and Engineering, B.A.Sc. (Class of 2027) (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/mathematics-engineering/mathematics-engineering-basc-class-2027/)
- Mathematics and Engineering, Applied Mechanics (M6): Technical Electives (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/mathematics-engineering/mathematics-engineering-applied-mechanics-m6-technical-electives/)
- Mathematics and Engineering, Computing and Communications (M9): Technical Electives (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/mathematics-engineering/mathematics-engineering-computing-communications-m9-technical-electives/)
- Mathematics and Engineering, Systems and Robotics (M11): Technical Electives (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/mathematics-engineering/mathematics-engineering-systems-robotics-m11-technical-electives/)

Courses

MTHE 212 Linear Algebra Units: 3.50
Vector spaces, direct sums, linear transformations, eigenvalues, eigenvectors, inner product spaces, self-adjoint operators, positive operators, singular-value decomposition, minimal polynomials, Jordan canonical form, the projection theorem, applications to approximation and optimization problems.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 174 Corequisites: Exclusions: MTHE 312 (MATH 312)
Offering Term: W
CEAB Units:
Mathematics 42
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Smith Engineering
Course Learning Outcomes:

1. Computing eigenvalues and eigenvectors of endomorphisms.
2. Computing Jordan Normal Forms of endomorphisms.
3. Proving properties of homomorphisms between vector spaces, as well as properties of eigenvalues and eigenvectors of endomorphisms.
4. Working with the properties of inner-products and Hilbert spaces.

MTHE 217 Algebraic Structures with Applications Units: 3.50
Introduction to algebraic systems and structures, and their engineering applications. Topics include symbolic logic; switching and logic circuits; set theory, equivalence relations and mappings; the integers and modular arithmetic; groups, cyclic groups, Lagrange's theorem, group quotients, group homomorphisms and isomorphisms; applications to error-control codes for noisy communication channels.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 174 Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 18
Natural Sciences 0
Complementary Studies 0
Engineering Science 16
Engineering Design 8
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Proving basic results on relations and functions as well as basic results in set theory and number theory.
2. Proving basic results in group theory.
3. Showing an understanding of groups, subgroups, and group homomorphisms.
4. Proficiency in symbolic logic.
5. Using linear algebraic and group theoretic tools to model and analyze error-correcting codes.

MTHE 224 Applied Math For Civil Eng. Units: 4.20
The course will discuss the application of linear differential equations with constant coefficients, and systems of linear equations within the realm of civil engineering. Additionally, the course will explore relevant data analysis techniques including: graphical and statistical analysis and presentation of experimental data, random sampling, estimation using confidence intervals, linear regression, residuals and correlation.
(Lec: 3, Lab: 0.4, Tut: 0.8)
Requirements: Prerequisites: APSC 142 or APSC 143 or MNTC 313, APSC 172, APSC 174 Corequisites: Exclusions: MTHE 225 (MATH 225), MATH 226, MTHE 235 (MATH 235), MTHE 237 (MATH 237), STAT 267, MTHE 367 (STAT 367)
Offering Term: F
CEAB Units:
Mathematics 50
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing the sample mean and standard deviation from summary data.
2. Computing basic statistical quantities such as median and quantiles from data.
3. Verifying solutions of ordinary differential equations.
4. Using Euler's method to compute approximate solutions of ordinary differential equations.
5. Using probability theory to solve problems of quality control.
6. Modeling and analyzing physical processes using differential equations.
7. Analyzing empirical data for quality control purposes.

MTHE 225 Ordinary Differential Equations Units: 3.50
First order differential equations, linear differential equations with constant coefficients, and applications, Laplace transforms, systems of linear equations.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 171, APSC 172, APSC 174
Corequisites: Exclusions:
Offering Term: FWS
CEAB Units:
Mathematics 42
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Course Equivalencies: MATH225;MTHE225
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Solving basic initial value problems.
2. Solving linear constant coefficient differential equations.
3. Using the Laplace transform to solve differential equations.
4. Modeling a mass-spring-damper system or RLC circuit using differential equations.
5. Modeling interconnected fluid reservoirs using differential equations.

MTHE 227 Vector Analysis Units: 3.00
Review of multiple integrals. Differentiation and integration of vectors; line, surface and volume integrals; gradient, divergence and curl; conservative fields and potential. Spherical and cylindrical coordinates, solid angle. Green's and Stokes' theorems, the divergence theorem.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: APSC 171, APSC 172, APSC 174
Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 36
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing path integrals.
2. Computing the flux of a vector field across a surface.
3. Computing the circulation of a vector field around a boundary.
4. Modeling the area of a region bounded by a simple closed curve as an integral.
5. Modeling the volume enclosed by a closed surface as an integral.

MTHE 228 Complex Analysis Units: 3.50
Complex arithmetic, complex plane. Differentiation, analytic functions. Elementary functions. Elementary functions. Contour integration, Cauchy's Theorem and Integral Formula. Taylor and Laurent series, residues with applications to evaluation of integrals.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 171, APSC 172, APSC 174
Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 42
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Evaluating contour integrals using residue theory.
2. Computing harmonic conjugates of harmonic functions.
3. Solving algebraic equations involving complex numbers.
4. Computing Taylor and Laurent expansions of complex analytic functions.
5. Proving basic properties of complex analytic functions.
6. Understanding basic properties of complex mappings.

MTHE 235 Diff Equations For Elec & Comp Units: 3.50
Topics include developing and analyzing mathematical models describing physical and natural phenomena and those arising in electrical engineering applications (such as circuits), classification of differential equations, methods for solving differential equations, Laplace Transform method, systems of differential equations and connections with Linear Algebra, stability of systems.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 171, APSC 172, APSC 174
Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 18
Natural Sciences 11
Complementary Studies 0
Engineering Science 13
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Solving basic initial value problems.
2. Using the Laplace transform to solve differential equations.
3. Computing Laplace and inverse Laplace transforms.
4. Find general solutions of ordinary differential equations.
5. Model an RLC circuit using ordinary differential equations.

MTHE 237 Differential Equations for Engineering Science Units: 3.50
Topics include developing and analyzing mathematical models describing physical and natural dynamical phenomena and those arising in various engineering system applications, classification of differential equations, methods for solving differential equations, Laplace Transform method, systems of differential equations and connections with Linear Algebra, stability of linear and nonlinear systems and Lyapunov's method.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 171, APSC 172, APSC 174
Corequisites: Exclusions: MATH 231, MTHE 232 (MATH 232)
Offering Term: F
CEAB Units:
Mathematics 16
Natural Sciences 11
Complementary Studies 0
Engineering Science 15
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Compute the general or particular solutions to linear and nonlinear differential equations, and systems of differential equations.
2. Understand the implications of the existence and uniqueness theorem and linear independence/ dependence properties of solutions to differential equations.
3. Develop mathematical models describing physical phenomena.
4. Use the method of Laplace transform to solve problems involving discontinuous forcing terms.
5. Determine stability of differential equations.

MTHE 280 Advanced Calculus Units: 3.50
Limits, Continuity, C', and linear approximations of functions of several variables. Multiple integrals and Jacobians, Line and surface integrals. The theorems of Green, Stokes, and Gauss.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 172, APSC 174
Corequisites: Exclusions: MATH 221, MTHE 227 (MATH 227)
Offering Term: F
CEAB Units:
Mathematics 42
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Demonstrate use of concepts of continuity and differentiability in higher dimensions, including the use of the chain rule.
2. Demonstrate ability to parametrize and describe curves, surfaces, and solid regions in higher dimensions.
3. Integrate functions over parametrized regions to obtain line integrals, surface integrals, volume integrals.
4. Describe the physical meaning and use the differential operators: gradient, curl, and divergence.
5. Describe the physical meaning and use the three main theorems of multivariate calculus: Green's Theorem, Gauss's theorem, and Stokes's theorem.

MTHE 281 Introduction To Real Analysis Units: 3.50
Taylor's theorem, optimization, implicit and inverse function theorems. Elementary topology of Euclidean spaces. Sequences and series of numbers and functions. Pointwise and uniform convergence. Power series.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 172 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 42
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Determining convergence or divergence of a sequence of real numbers.
2. Determining uniform/pointwise convergence or divergence of a sequence of functions.
3. Proving properties of limits of sequences of functions.
4. Using definitions to prove relationships between types of subsets of Euclidean space.
5. Using the definition of continuity to prove properties of continuous functions.

MTHE 326 Functions of a Complex Variable Units: 3.50
Complex numbers, analytic functions, harmonic functions. Cauchy's theorem. Taylor and Laurent series. Calculus of residues. Rouche's theorem.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 280 (MATH 280), MTHE 281 (MATH 281) Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 42
Natural Sciences 0
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Solving algebraic equations involving complex numbers.
2. Computing path integrals of analytic functions using residue theory.
3. Computing Taylor and Laurent expansions for analytic functions of a complex variable.
4. Proving results on roots of polynomials using complex function theory.
5. Proving results on analytic functions.
6. Precise formulation of basic definitions and results on analytic functions.
7. Precise use of mathematical definitions in proving results on analytic functions.

MTHE 328 Real Analysis Units: 3.00
Topological notions on Euclidean spaces, continuity and differentiability of functions of several variables, uniform continuity, extreme value theorem, implicit function theorem, completeness and Banach spaces, Picard-Lindelöf theorem, applications to constrained optimization and Lagrange multipliers, and existence/uniqueness of solutions to systems of differential equations.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 281 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 28
Natural Sciences 8
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Smith Engineering
Course Learning Outcomes:

1. Understand and distinguish various topological notions for subsets of the real line and of the n-dimensional Euclidean space, such as interior and boundary points, open/closed sets, cluster points, isolated points, nowhere dense sets, compact sets, connected sets, G-delta and F-sigma sets.
2. Understand and apply the concept of limit, continuity for functions of several real variables, and their ramifications, such as the intermediate value theorem and the extreme value theorem. Understand and apply the concept of uniform continuity and its ramification, such as the Heine-Cantor theorem. Understand and distinguish sets of continuity and their properties.
3. Understand and apply the concept of differentiability for (possibly vector-valued) functions of several real variables and its ramifications. For instance, apply the chain rule, the inverse function theorem, and the implicit function theorem in concrete examples. Understand differentiability and gradients in terms of partial derivatives.
4. Understand and apply the concept of relative extrema for functions of several variables and their relation to the Jacobian and the Hessian. Understand and apply the concept of constrained extrema and the Lagrange Multiplier Theorem in concrete examples.
5. Understand and apply the Picard-Lindelöf theorem to study the existence and uniqueness of solutions of systems of ordinary differential equations.

MTHE 332 Introduction To Control Units: 4.00
Modeling control systems, linearization around an equilibrium point. Block diagrams, impulse response, transfer function, frequency response. Controllability and observability, LTI realizations. Feedback and stability, Lyapunov stability criterion, pole placement, Routh criterion. Input/output stability, design of PID controllers, Bode plots, Nyquist plots, Nyquist stability criterion, robust controllers. Laboratory experiments illustrate the control concepts learned in class.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0.5, Tut: 0.5)
Requirements: Prerequisites: MTHE 326 (MATH 326) Corequisites: MTHE 335 Exclusions:
Offering Term: W
CEAB Units:
Mathematics 15
Natural Sciences 5
Complementary Studies 0
Engineering Science 23
Engineering Design 5
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Linearizing a nonlinear control system around an equilibrium point.
2. Computing the controllability and observability matrices of a linear time invariant system.
3. Determining internal stability of a linear time invariant system.
4. Making rigorous use of notions from linear algebra and differential equations in proving results on linear time invariant systems.
5. Using tools from linear algebra and differential equations to determine properties of linear time invariant systems.
6. Control of an electromechanical system.
7. Formulates clear problem specifications for the design of control systems.
8. Develops metrics for comparing designs of controllers.

MTHE 334 Math Methods For Engrg & Phys Units: 3.50
Banach and Hilbert spaces of continuous- and discrete-time signals; spaces of continuous and not necessarily continuous signals; continuous-discrete Fourier transform; continuous-continuous Fourier transform; discrete-continuous Fourier transform; discrete-discrete Fourier transform; transform inversion using Fourier series and Fourier integrals.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 212 (MATH 212), MTHE 281 (MATH 281) Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 28
Natural Sciences 0
Complementary Studies 0
Engineering Science 14
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Constructing or verifying discrete- and continuous-times signals with prescribed behaviour in the time-domain.
2. Constructing or verifying discrete- and continuous-times signals with prescribed behaviour in the frequency-domain.
3. Understanding discrete- and continuous-time signal spaces with ∞- and Lp-norms.
4. Understanding the four Fourier transforms and how they are related and not related.
5. Understanding and explaining the role of Lebesgue measure in continuous-time signal analysis.
6. Proving relationships between spaces of discrete- and continuous-time signals

MTHE 335 Mathematics of Engineering Systems Units: 3.50
Review of signal spaces arising in systems theory and applications, such as linear spaces, Banach and Hilbert spaces, and distributions. Approximation and representation of signals. Discrete and continuous Fourier Transforms, Laplace and Z transforms. Linear input/output systems and their stability and regularity analysis. Frequency-domain and time-domain analysis of linear time-invariant systems. Applications to modulation of communication signals, linear filter design, system design, control design, and digital sampling.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 326 or MTHE 228 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 8
Natural Sciences 6
Complementary Studies 0
Engineering Science 14
Engineering Design 14
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Understand input-output systems and their properties such as stability and time-invariance.
2. Solve a difference or differential equation using the z-transform or the Laplace transform.
3. Prove results on the Fourier transform.
4. Prove results on distributions.
5. Investigate the possibility of signal representations through polynomials, Haar wavelets and harmonic signals and their use in system theoretic analysis.
6. Understand mathematical analysis of signal sampling.
7. Design control systems via frequency domain (Fourier/Laplace/Z transform) methods.
8. Formulate and design lowpass filters and noise removal algorithms.
9. Use mathematics to develop algorithms for noise removal.

MTHE 337 Intro. To Operations Research Units: 3.00
Topics include Markov chains, Introduction to dynamic programming and Markov Decision Processes, simulation, queuing theory, inventory theory, and introduction to reinforcement learning.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 351 or permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 18
Natural Sciences 0
Complementary Studies 0
Engineering Science 9
Engineering Design 9
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Compute optimal policies via dynamic programming in applications such as inventory control.
2. Understand stability of queuing models.
3. Establish optimal decision and planning via various methods.
4. Rigorously prove results in Markov chains and optimal planning/control using tools from mathematical analysis.

MTHE 338 Fourier Methods for Boundary Value Problems Units: 3.50
Methods and theory for ordinary and partial differential equations; separation of variables in rectangular and cylindrical coordinate systems; sinusoidal and Bessel orthogonal functions; the wave, diffusion, and Laplace's equation; Sturm-Liouville theory; Fourier transform techniques.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 227 (MATH 227) or MTHE 280 (MATH 280), MTHE 237 (MATH 237) or MTHE 225 (MATH 225), or permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 28
Natural Sciences 0
Complementary Studies 0
Engineering Science 14
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing Fourier series expansions of functions.
2. Computing solutions to boundary value problems.
3. Proving that a given Sturm-Liouville problem has only positive eigenvalues.
4. Selection of Fourier integral or Fourier series for representation of harmonic functions.

MTHE 339 Evolutionary Game Theory Units: 3.00
This course highlights the usefulness of game theoretical approaches in solving problems in the natural sciences and economics. Basic ideas of game theory, including Nash equilibrium and mixed strategies; stability using approaches developed for the study of dynamical systems, including evolutionary stability and replicator dynamics; the emergence of co-operative behaviour; limitations of applying the theory to human behaviour.
NOT OFFERED 2024-2025.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: APSC 172 or MATH 120 (or MATH 121); APSC 174 or MATH 110 (or MATH 111) recommended Corequisites: Exclusions: MATH 239
Offering Term: W
CEAB Units:
Mathematics 18
Natural Sciences 9
Complementary Studies 9
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing expected payoffs of games.
2. Using backward induction to find solutions to games in extensive form.
3. Using iterated elimination of dominated strategies to find a solution to games in normal form.
4. Using the theorem of mixed strategy Nash equilibria to find solutions to games in normal form.
5. Finding the Nash equilibria of a game.

MTHE 351 Probability I Units: 3.50
Introduction to probability theory and its applications in engineering science: basic concepts of probability, counting, conditional probability, Bayes' rule, independence; probability models; random variables, distribution functions, probability mass functions, probability density functions; expectation, variance, moments; jointly distributed random variables; transformations of random variables. Distributions: Bernoulli, binomial, geometric, negative binomial, Poisson, uniform, exponential, normal. Applications: elementary stochastic processes, noisy communication channels.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: Corequisites: MTHE 280 Exclusions: STAT 251
Offering Term: F
CEAB Units:
Mathematics 20
Natural Sciences 0
Complementary Studies 0
Engineering Science 22
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing the probability density function of a function of a random variable.
2. Computing probabilities of events defined by random variables and computing moments of random variables.
3. Computing joint probability density functions of random variables.
4. Computing joint probability density functions of random variables.
5. Reasoning probabilistically in order to solve problems of quality control.
6. Rigorously establishing relations between probabilities or conditional probabilities of various events.

MTHE 353 Probability II Units: 3.00
Intermediate probability theory as a basis for further study in mathematical statistics and stochastic processes and applications; probability measures, expectations; modes of convergence of sequences of random variables; conditional expectations; independent systems of random variables; Gaussian systems; characteristic functions; Law of large numbers, Central limit theory; some notions of dependence.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: STAT 251 or MTHE 351 (STAT 351), APSC 174, MTHE 281 (MATH 281) Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 26
Natural Sciences 0
Complementary Studies 0
Engineering Science 10
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing probabilities of events defined by random variables.
2. Reasoning probabilistically in order to solve problems of sampling with or without replacement.
3. Using mathematics in order to estimate the probability of certain events.
4. Rigorously proving results in probability theory using tools from mathematical analysis.

MTHE 367 Engineering Data Analysis Units: 3.50
Exploratory data analysis -- graphical and statistical analysis and presentation
of experimental data. Random sampling. Probability and probability models
for discrete and continuous random variables. Process capability. Normal probability graphs. Sampling distribution of means and proportions. Statistical Quality Control and Statistical Process Control. Estimation using confidence intervals. Testing of hypothesis procedures for means, variances and
proportions -- one and two samples cases. Liner regression, residuals and correlation. ANOVA. Use of statistical software.
NOT OFFERED 2023-2024
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 171, APSC 172 Corequisites: Exclusions: STAT 261, STAT 263, STAT 266, STAT 267
Offering Term: W
CEAB Units:
Mathematics 31
Natural Sciences 0
Complementary Studies 0
Engineering Science 11
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Performing calculations for confidence intervals and hypothesis tests in various situations involving one, two, and three or more samples, including simple linear regression and one-way analysis of variance.
2. Computing values of random variables or probabilities associated with random variables.
3. Conversion of physical problem into appropriate statistical model.
4. Solving statistics problems using probability or Poisson or Normal or Exponential distributions or simple linear regression or analysis of variance.
5. Recognizing the design of experiments performed and/or performing appropriate statistical analysis to solve engineering problems.
6. Analysis of data using statistical tools and derivation of suitable conclusions from empirical data.

MTHE 393 Engineering Design and Practice for Mathematics and Engineering Units: 4.00
This is a project-based design course where methods of applied mathematics are used to solve a complex open-ended engineering problem. The projects involve using system theoretic methods for modeling, analysis, and design applied to engineering problems arising in a variety of engineering disciplines. Students will work in teams and employ design processes to arrive at a solution. The course will include elements of communications, economic analysis, impacts of engineering, professionalism, and engineering ethics.
K4(Lec: Yes, Lab: Yes, Tut: Yes)
Requirements: Prerequisites: APSC 200 or APSC 202
Corequisites: MTHE 335 Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 12
Engineering Science 0
Engineering Design 36
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Construct or select appropriate mathematical models.
2. Generate a traceable and defensible record of technical projects using an appropriate records system.
3. Consider all factors in design, including economic, environmental, social, and regulatory considerations, as appropriate.
4. Develop mathematical tools to solve engineering problems.
5. Demonstrate a capacity for leadership and decision-making.
6. Interpret communication from a variety of sources and responds to instructions and questions while displaying a full understanding of the topic.
7. Demonstrate professional bearing.
8. Consider social and environmental factors and/or impacts in decisions.
9. Consider ethical factors and matters of equity as appropriate.
10. Perform economic analysis at an appropriate level.
11. Demonstrate skills needed for self-education.
12. Demonstrate proficiency in using sophisticated mathematical models in analysis of engineering problems.
13. Experimentally validate mathematical models and techniques.
14. Formulate clear problem specifications.
15. Understand limitations of mathematical tools.

MTHE 406 Introduction To Coding Theory Units: 3.00
Construction and properties of finite fields. Polynomials, vector spaces, block codes over finite fields. Hamming distance and other code parameters. Bounds relating code parameters. Cyclic codes and their structure as ideals. Weight distribution. Special codes and their relation to designs and projective planes. Decoding algorithms.
NOT OFFERED 2024-2025.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 217 (MATH 217)
Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 14
Natural Sciences 0
Complementary Studies 0
Engineering Science 12
Engineering Design 10
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Understanding the structure of finite fields.
2. Rigorously proving results on error correction and detection.
3. Deriving bounds and asymptotic bounds for codes.
4. Probabilistic or combinatorial analysis for coding and decoding.
5. Designing linear codes given real-world parameters.

MTHE 418 Number Theory & Cryptography Units: 3.00
Time estimates for arithmetic and elementary number theory algorithms (division algorithm, Euclidean algorithm, congruences), modular arithmetic, finite fields, quadratic residues. Simple cryptographic systems; public key, RSA. Primality and factoring: pseudoprimes, Pollard's rho-method, index calculus. Elliptic curve cryptography.
NOT OFFERED 2024-2025.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 217 (MATH 217) or MATH 210 or MATH 211 with permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 18
Natural Sciences 0
Complementary Studies 0
Engineering Science 9
Engineering Design 9
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computations and constructions in finite fields.
2. Reasoning on elliptic curves.
3. Understanding of the algebraic structure of a group.
4. Rigorously proving results in number theory.
5. Probability analysis of primality tests.
6. Analysis of cryptographic protocols.
7. Designing a cryptographic system with given real-world parameters.
8. Testing various designs to determine which performs the best.

MTHE 430 Control Theory Units: 4.00
This course covers core topics in both classical and modern control theory. Overview of classical control theory using frequency methods. Linear and nonlinear controlled differential systems and their solutions. Stabilization and stability methods via Lyapunov analysis or linearization. Controllability, observability, minimal realizations, feedback stabilization, observer design. Optimal control theory, the linear quadratic regulator, dynamic programming.
(Lec: 3, Lab: 0.5, Tut: 0.5)
Requirements: Prerequisites: MTHE 237, MTHE 212, MTHE 326, or permission of the instructor Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 6
Natural Sciences 6
Complementary Studies 0
Engineering Science 18
Engineering Design 18
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Linearize a nonlinear system around a given trajectory.
2. Construct LTI realizations of given transfer functions.
3. Determine the controllability/observability properties of a linear time varying system.
4. Rigorously use concepts from linear algebra/differential equations in proving results on linear control systems.
5. Use tools from optimal control theory in order to solve optimization problems.
6. Use tools from linear algebra in order to construct stabilizing controllers.
7. Experimentally study linear approximations to nonlinear systems and the limits of validity of linearization.
8. Experimentally study finite dimensional linear approximations to infinite dimensional linear systems and the limits of validity of that approximation.

MTHE 433 Continuum Mechanics with Applications Units: 3.50

Continuum mechanics lays the foundations for the study of the mechanical behavior of solids and fluids. After a review of vector and tensor analysis, the kinematics of continua are introduced. Emphasis is given to the concepts of stress, strain and deformation. The fundamental laws of conservation of mass, balances of (linear and angular) momentum and energy are presented together with the constitutive models. Applications of these models are given in the theory of linearized elasticity and fluid dynamics.

(Lec: 3, Lab: 0, Tut: 0.5)

Requirements: Prerequisites: MTHE 237, MTHE 280, or permission of the instructor Corequisites: Exclusions:

Offering Term: F

CEAB Units:

Mathematics 6
Natural Sciences 0
Complementary Studies 0
Engineering Science 24
Engineering Design 12

Offering Faculty: Faculty of Arts and Science

Course Learning Outcomes:

1. Understand definitions and techniques of tensor algebra and tensor calculus.
2. Use the methods of tensor algebra and calculus for the description of the deformation of a body.
3. Use the methods of tensor algebra and calculus to describe the motion of a body.
4. Compute tractions, principal stresses, and principal axes of stress of a body.
5. Formulate the differential equations governing the motion of a body.
6. Develop engineering solutions for real-world problems concerned with stress of materials, deformation of elastic bodies and motion of fluids.

MTHE 434 Optimization Theory with Applications to Machine Learning Units: 3.50

Theory of convex sets and functions; separation theorems; primal-dual properties; geometric treatment of optimization problems; algorithmic procedures for solving constrained optimization programs; applications of optimization theory to machine learning.

NOT OFFERED 2024-2025

(Lec: 3, Lab: 0, Tut: 0.5)

Requirements: Prerequisites: MTHE 281 (MATH 281), MTHE 212 (MATH 212), or permission of the instructor Corequisites: Exclusions:

Offering Term: W

CEAB Units:

Mathematics 15
Natural Sciences 0
Complementary Studies 0
Engineering Science 15
Engineering Design 12

Offering Faculty: Smith Engineering

Course Learning Outcomes:

1. Computing necessary conditions for optimality.
2. Solving constrained optimization problems.
3. Understanding the mathematical properties of convex sets and convex functions.
4. Rigorously using separation theorems for solving optimization problems.
5. Using numerical methods in the study of optimization problems.
6. Solving resource allocation problems using duality theory.

MTHE 436 Partial Differential Equations Units: 3.00
Well-posedness and representation formulae for solutions to the transport equation, Laplace equation, heat equation, and wave equation. Fundamental solutions. Properties of harmonic functions. Green's function. Mean value formulae. Energy methods. Maximum principles. Method of characteristics for quasilinear equations. Burgers' equation. Shocks formation and entropy condition. Applications to fluid dynamics, elasticity problems and/or optimization problems.
NOT OFFERED 2024-2025.
(Lec: 3, Lab: 0 Tut: 0)
Requirements: Prerequisites: MTHE 237, MTHE 280 or permission of the instructor Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 18
Natural Sciences 6
Complementary Studies 0
Engineering Science 12
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

MTHE 437 Topics In Applied Mathematics Units: 3.50
Topic: An Introduction to Stochastic Differential Equations (with Applications to Mathematical Finance and Engineering)
The aim of this course is to provide a rigorous introduction to the theory of stochastic calculus and stochastic differential equations, and to survey some of its most important applications, especially in Mathematical Finance. The Ito stochastic integral and its associated Ito Calculus will be derived in the general framework of continuous semimartingales, leading to a detailed treatment of stochastic differential equations (SDEs) and their properties. The theory thus developed will be applied to selected problems in Mathematical Finance (option pricing and hedging, trading strategies and arbitrage) and Engineering (boundary-value problems, filtering, optimal control). Numerical aspects of SDEs will also be discussed.
NOT OFFERED 2024-2025.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 328 and MTHE 351, or permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 18
Natural Sciences 0
Complementary Studies 0
Engineering Science 12
Engineering Design 12
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Using the Ito calculus in the study of stochastic processes.
2. Determining (local) martingale properties of stochastic processes defined through stochastic integration.
3. Rigorous understanding of Brownian motion and its main properties.
4. Rigorous understanding of the Ito stochastic integral and its properties.
5. Rigorously using results from martingale theory in establishing properties of stochastic processes.
6. Using tools from stochastic analysis in the study of uniformly elliptic partial differential equations.

MTHE 439 Lagrangian Mechcanics, Dynamics Control Units: 3.50
Geometric modelling, including configuration space, tangent bundle, kinetic energy, inertia, and force. Euler-Lagrange equations using affine connections. The last part of the course develops one of the following three applications: mechanical systems with nonholonomic constraints; control theory for mechanical systems; equilibria and stability.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 280 (MATH 280), MTHE 281 (MATH 281), MTHE 237 (MATH 237) or MATH 231, or permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 20
Natural Sciences 0
Complementary Studies 0
Engineering Science 11
Engineering Design 11
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Understand the definitions and constructions from differential geometry.
2. Translate physical concepts to differential geometric concepts.
3. Use the methods of differential geometry.
4. Model physical systems using methods of geometric mechanics.

MTHE 454 Statistical Spectrum Estimation Units: 3.00
Many systems evolve with an inherent amount of randomness in time and/or space. The focus of this course is on developing and analyzing methods for analyzing time series. Because most of the common time--domain methods are unreliable, the emphasis is on frequency--domain methods, i.e. methods that work and expose the bias that plagues most time--domain techniques. Slepian sequences (discrete prolate spheroidal sequences) and multi--taper methods of spectrum estimation are covered in detail.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 353 (STAT 353), MTHE 312 (MATH 312); or MTHE 338 (MATH 338), STAT 251; or STAT 261, MATH 321; or permission or the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 12
Natural Sciences 0
Complementary Studies 0
Engineering Science 12
Engineering Design 12
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

MTHE 455 Stochastic Processes & Applications Units: 3.50
Markov chains, birth and death processes, random walk problems, elementary renewal theory, Markov processes, Brownian motion and Poisson processes, queuing theory, branching processes.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 353 (STAT 353) or one of STAT 251, MTHE 351 (STAT 351), ELEC 326 with permission of the instructor Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 28
Natural Sciences 0
Complementary Studies 0
Engineering Science 14
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Compute an expectation using conditioning.
2. Convert a process description into a Markov chain model.
3. Understand the mathematical structure of a Markov chain.
4. Identify the stationary distribution of Markov chains.
5. Prove results about Markov chains.
6. Compute an expectation using Markov Chain Monte Carlo.

MTHE 457 Statistical Learning Units: 3.00
Introduction to the theory and application of statistical algorithms. Topics include classification, smoothing, model selection, optimization, sampling, supervised and unsupervised learning.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 351 or equivalent Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 12
Natural Sciences 0
Complementary Studies 0
Engineering Science 24
Engineering Design 0
Offering Faculty: Smith Engineering
Course Learning Outcomes:

1. Understand regression problems and algorithms.
2. Understand the bias variance trade-off.
3. Understand classification problems and algorithms.
4. Perform supervised learning tasks on real-world datasets.
5. Understand concepts in unsupervised learning problems.

MTHE 472 Optimization and Control of Stochastic Systems Units: 3.50
This course concerns the optimization, control, and stabilization of dynamical systems under probabilistic uncertainty with applications in engineering systems and applied mathematics. Topics include: controlled and control-free Markov chains and stochastic stability; martingale methods for stability and stochastic learning; dynamic programming and optimal control for finite horizons, infinite horizons, and average cost problems; partially observed models, non-linear filtering and Kalman Filtering; linear programming and numerical methods; reinforcement learning and stochastic approximation methods; decentralized stochastic control, and continuous-time stochastic control.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 351 or permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 6
Natural Sciences 0
Complementary Studies 0
Engineering Science 18
Engineering Design 18
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Understand stochastic stability notions for Markov chains, including recurrence, positive Harris recurrence, and transience.
2. Establish the existence and structure of optimal policies for finite horizon, discounted infinite horizon and average cost infinite horizon problems.
3. Investigate the applicability of computational or learning theoretic methods for stochastic control problems.
4. Understand linear and non-linear filtering theory and their use in engineering systems.
5. Arrive at solutions for optimality, near-optimality, or stability in decision making under uncertainty via alternative analytical, numerical or simulation methods.
6. Document, present, and critically review a scientific paper, method or algorithm on a subject involving stochastic control theory or applications.

MTHE 474 Information Theory Units: 3.50
Topics include: information measures, entropy, mutual information, modeling of information sources, lossless data compression, block encoding, variable-length encoding, Kraft inequality, fundamentals of channel coding, channel capacity, rate-distortion theory, lossy data compression, rate-distortion theorem.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: STAT 251 or MTHE 351 (STAT 351) or ELEC 326 Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 6
Natural Sciences 0
Complementary Studies 0
Engineering Science 23
Engineering Design 13
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Computing Shannon's information measures (entropy, Kullback-Leibler distance and mutual information).
2. Computing the capacity of communication channels.
3. Reasoning about the properties of Shannon's information measures (entropy, Kullback-Leibler distance and mutual information).
4. Using mathematical tools to infer properties of coding and communication systems.
5. Probabilistic modeling of communication systems for source and channel coding purposes.
6. Using tools from probability theory to analyze communication systems.
7. Metric assessment of data compression code designs.

MTHE 477 Data Compression and Source Coding: Theory and Algorithms Units: 3.00
Topics include: arithmetic coding, universal lossless coding, Lempel-Ziv and related dictionary based methods, rate-distortion theory, scalar and vector quantization, predictive and transform coding, applications to speech and image coding.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 474 (MATH 474) Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 21
Engineering Design 15
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Prove rigorously the optimality of lossless and lossy source codes.
2. Design of quantizers and evaluation of distortion.
3. Mathematically formulate source coding problems.
4. Use probabilistic tools to understand the effect of data compression on random sources.

MTHE 478 Topics In Communication Theory Units: 3.00
Subject matter will vary from year to year. Possible subjects include: constrained coding and applications to magnetic and optical recording; data compression; theory and practice of error-control coding; design and performance analysis of communication networks; and other related topics.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: Permission of the instructor Corequisites: Exclusions:
Offering Term: FW
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 18
Engineering Design 18
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

MTHE 484 Data Networks Units: 3.00
This course covers performance models for data networking, delay models and loss models; analysis of multiple access systems, routing, and flow control; multiplexing; priority systems; satellite multiple access, wireless networking, wireless sensor networks. Knowledge of networking protocols is not required.
NOT OFFERED 2024-2025.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: MTHE 455 (STAT 455) or permission of the instructor Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 10
Natural Sciences 0
Complementary Studies 0
Engineering Science 26
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

MTHE 493 Engineering Math Project Units: 7.50
This is the capstone design course for Mathematics and Engineering. Students must work in groups. Projects are selected early in the year from a list put forward by Mathematics and Engineering faculty members who will also supervise the projects. There is a heavy emphasis on engineering design and professional practice. All projects must be open-ended and design oriented, and students are expected to undertake and demonstrate, in presentations and written work, a process by which the design facets of the project are approached. Projects must involve social, environmental, and economic factors, and students are expected to address these factors comprehensively in presentations and written work. Students are assessed individually and as a group on their professional conduct during the course of the project.
K7.5(Lec: No, Lab: Yes, Tut: Yes)
Requirements: Prerequisites: MTHE 393 and must be registered in BSCE or BASC program. Corequisites: Exclusions:
Offering Term: FW
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 10
Engineering Science 10
Engineering Design 70
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Demonstrate appropriate referencing to cite previous work.
2. Integrate standards, codes of practice, and legal and regulatory factors into decision- making processes, as appropriate.
3. Evaluate trade-offs among goals and concepts.
4. Have ability to understand the scope and a project, and how to manage the day-to-day and long-term facets of a project.
5. Critically evaluate procured information for authority, currency, and objectivity.
6. Conduct investigations to test hypotheses related to complete problems.
7. Independently acquire new knowledge and skills for ongoing personal and professional development.
8. Use graphics appropriately to explain, interpret, and assess information.
9. Develop metrics for comparison of designs.
10. Demonstrate accurate use of technical vocabulary.
11. Present oral communication that is well thought out, well-prepared, and delivered in a convincing manner.
12. Select appropriate mathematical models and tools.

MTHE 494 Mathematics and Engineering Seminar Units: 3.00
This is a seminar course, with an emphasis on communication skills and professional practice. A writing module develops technical writing skills. Students give an engineering presentation to develop their presentation skills. Seminars are given by faculty from the Mathematics and Engineering program, by Mathematics and Engineering alumni on the career paths since completing the program, and by visiting speakers on a variety of professional practice matters, on topics such as workplace safety, workplace equity and human rights, and professional organizations. Open to Mathematics and Engineering students only.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: Must be registered in BSCE or BASC program. Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 26
Engineering Science 10
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.