# School of Mathematics

# Study Abroad Module Handbook 2024/25

**Module Title:**LI Algebra & Combinatorics 1

**Module Code:**27363

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LI

**Module Description:** Combinatorics is the study of discrete (often finite) structures that arise not only in areas of pure mathematics, but in other areas of science, for example computer science, statistical physics and genetics. From ancient beginnings, this subject truly rose to prominence from the mid-20th century, when scientific discoveries (most notably of DNA) showed that combinatorics is key to understanding the world around us, whilst many of the great advances in computing were built on combinatorial foundations.

The combinatorics half of this module starts by looking at naive set theory, introducing the notions of partitions, equivalence relations and the notion of countable and uncountable infinite sets. Sophisticated counting techniques are developed before an introduction to the field of graph theory, which provides a mathematical framework for the study of both real-world and virtual networks.

One of the most powerful techniques of pure mathematics is that of abstraction, which allows deep relationships between apparently unrelated areas to become apparent. Abstract algebra is a powerful example of this technique, abstracting notions of symmetry and the properties of arithmetic to reveal algebraic structures such as groups, rings and fields. Despite their very abstract nature, these ideas have significant real world applications, for example in communication theory and internet security. Using familiar examples of the natural numbers, real numbers and polynomials as motivation, the axioms for groups, rings and fields are introduced and basic properties of these structures are explored. Elementary number theory, the Euclidean algorithm, and prime numbers are discussed. Underlying themes throughout this module are techniques of proof and the importance of mathematical writing.

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**Module Title:**LI Mechanics

**Module Code:**27345

**Semester:**2

**Credits:**10

**Level:**LI

**Module Description:** Classical or Newtonian mechanics is the foundation of applied mathematics and is an astonishingly powerful tool for explaining physical systems, from projectiles to planetary motion to the design of racing cars. It acts as a natural starting point for any serious discussion of mathematical modelling in broader areas. This module uses ideas such as forces, moments, Newton's Laws of Motion and energy to model practical situations. These models can then be analysed using a wide range of techniques from pure mathematics such as trigonometry, algebra, calculus and, in particular, vector methods. Real world problems are used to illustrate the theory and some surprising and counter-intuitive examples are discussed.

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**Module Title:** LI Probability & Statistics

**Module Code**: 25663 / 26709

**Semester:**2

**Credits:**10

**Level:** LI

**Module Description:** Statistics, often regarded as distinct science rather than a branch of mathematics, is the study of data and uncertainty. Statistical techniques allow us to make conclusions, such as whether or not living near electricity pylons is dangerous, from sets of data. Statistics is also used in the design of effective experiments and in determining what data should be collected. For example, statistical techniques might be used to determine the frequency with which aircraft components should be tested for safety.

Underlying these techniques is the assumption that these data are samples of a random variable that follows a probability distribution describing their behaviour. This module provides an introduction to probability and statistics. Axiomatic probability theory, including Bayes’ Theorem, is discussed briefly. Key discrete and continuous probability modules (such as the binomial, Poisson and normal distributions) are introduced. Properties of expectation and variance are discussed. The Weak Law of Large Numbers and the Central Limit Theorem are covered before basic statistical ideas, such as statistical inference and hypothesis testing are introduced. Real world data are used to illustrate the theory.

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**Module Title:**LI Mathematics in Industry

**Module Code:**25668

**Semester:**1

**Credits:**10

**Level:**LI

**Module Description:** This module aims to develop the professional skills that employers expect of mathematics graduates. It focuses on developing problems solving abilities and team-working skills, particularly with reference to the types of poorly specified problems encountered in industry. The ability to present mathematical ideas to expert and non-expert audiences, through presentations, short reports and poster presentations is also developed. The module will be enhanced through sessions run by employers and recent alumni.

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**Module Title:**LI / LH Linear Algebra & Linear Programming

**Module Code:**25765 / 28512

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LI / LH

**Module Description:** Linear algebra grew out of the development of techniques at the start of the 18th century by Leibniz, Cramer and Gauss to solve systems of linear equations. Cayley developed matrix algebra in the middle of the 19th century and the definition of a vector space was made by Peano at the end of the 19th century, resulting in a theory of linear transformations and vector spaces in the early 20th century. Linear algebra is not only fundamental to both pure and applied mathematics, but also has applications ranging from quantum theory to Google search algorithms.

This module develops the theory of vector spaces introduced in Vectors, Geometry & Linear Algebra, covering eigenvectors, characteristic polynomials, inner products, and diagonalization.If linear algebra grew out of the solution of systems of linear equations, then linear programming grew out of attempts to solve systems of linear inequalities, allowing one to optimise linear functions subject to constraints expressed as inequalities.

The theory was developed independently at the time of World War II by the Soviet mathematician Kantorovich, for production planning, and by Dantzig, to solve complex military planning problems. Koopmans applied it to shipping problems and the technique enjoyed rapid development in the postwar industrial boom. The first complete algorithm to solve linear programming problems, called the simplex method, was published by Dantzig in 1947 and in the same year von Neumann established the theory of duality. In 1975, Kantorovich and Koopmans shared the Nobel Prize in Economics for their work and Dantzig’s simplex method has been voted the second most important algorithm of the 20th century after the Monte Carlo method. Linear programming is a modern and immensely powerful technique that has numerous applications, not only in business and economics, but also in engineering, transportation, telecommunications, and planning.

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**Module Title:**LI Numerical Methods & Programming

**Module Code:**25669

**Semester:**1

**Credits:**10

**Level:**LI

**Module Description:** Many problems arising in mathematics cannot be solved exactly. In such cases, one approach is to use numerical methods implemented on a computer to find approximate but nevertheless usefully accurate solutions. This module introduces the basic techniques of such numerical methods, involving one or more computer packages, and uses these to illustrate and explore mathematics graphically and numerically, perform numerical routines, and run simulations involving random numbers. At the same time, it the basic ideas of computer programming are introduced such as writing simple programmes, the process of debugging code and the sources and effects of errors in the use of floating point numbers.

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**Module Title:**LI / LH Algebra & Combinatorics 2

**Module Code:**25665 / 27142

**Semester:**2

**Credits:**20

**Level:**LI / LH

**Module Description:** Algebra, or more accurately abstract algebra, extends the ideas of multiplication and addition in sets of matrices or real numbers to a more general setting. Abstraction allows us to view the results of specific calculations in a more generic setting. This is a core objective of pure mathematics. It means that a single theorem can be applied in many different mathematical situations. The primary algebraic objects are groups, rings and fields and these will be the main players in the algebra part of the module. This second module builds on the first year algebra course, extending results and producing new ideas which help us gain a deeper understanding of the algebraic structures which govern mathematics.

The fundamental notions which will be introduced are substructures, structure preserving functions and quotient structures and the course will introduce these ideas illustrating them with numerous examples. Combinatorics studies discrete mathematical structures. These structures are very simple themselves, but they often give rise to incredibly complex problems that are beyond the capacity of current computers to solve. Combinatorics is an essential component of many mathematical areas and also has important applications in Computer Science, Physics, Economics and Biology.

The Combinatorics part of the module consists of three topics. The first discusses advanced counting arguments, illustrating links to other areas of Mathematics. The second consists of topics in Graph Theory. There are many beautiful results in this area (e.g. the four colour theorem). These results are easily accessible but often require surprising ideas. The third topic builds on the previous two and deals with Combinatorial Algorithms and their efficiency, thus emphasizing links between Combinatorics and Computer Science.

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**Module Title:**LI / LH Multivariable & Vector Analysis

**Module Code:**25667 / 35175

**Semester:**1

**Credits:**20

**Level:**LI / LH

**Module Description:** Most models of real world situations depend on more than one variable and the techniques of calculus can be extended to solve problems arising in such situations. Typically these are problems whose solutions are functions of position, describing, for example, heat distribution or velocity potential, and involve the partial differentiation or multiple integration of functions of more than one variable. The theory and classification of stationary points of functions of two or more variables is developed allowing maxima and minima, including those subject to constraints, to be identified. The differential operators div, grad, curl and the Laplacian are introduced.

These are used in particular in the integral theorems (the Divergence theorem and the theorems of Green and Stokes) that relate line, surface and volume integrals and are used in the mathematical formulation of physical conservation laws. This module develops fundamental ideas that are used both in applied mathematics and in the development of analysis.

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**Module Title:**LI / LH Real & Complex Analysis (only available for full year study abroad)

**Module Code:**25666 / 27146

**Semester:**Full Term

**Credits:**20

**Level:**LI / LH

**Module Description:** This module starts by developing the theory of continuous and differentiable functions of one real variable introduced in Real Analysis and the Calculus. It places the familiar techniques of differentiation, such as the Chain Rule, on a firm theoretical foundation and proves some of the key results of real analysis such as the Intermediate Value Theorem, the Mean Value Theorem and Taylor’s Theorem. The basic theory of integration on a closed bounded interval is also developed. Differentiable functions of a single complex variable are then considered. This study reveals a deep and fundamental theory whose development, by some of the giants of mathematics, such as Euler, Gauss, Riemann and Cauchy, began at the end of the 18th century. This surprisingly elegant branch of mathematics, known as Complex Analysis, has many dramatic applications across mathematics, engineering and the physical sciences. It quickly provides us with powerful new techniques of integration and has far-reaching consequences in theoretical physics, electronics, fluid mechanics and thermodynamics. Underlying topological properties of Euclidean space common to both real and complex analysis are mentioned throughout the module.

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**Module Title:**LI / LH Differential Equations

**Module Code:**25670 / 27143

**Semester:**2

**Credits:**20

**Level:**LI / LH

**Module Description:** When mathematical modelling is used to describe physical, biological, chemical or other phenomena, one of the most common results is either a differential equation or a system of differential equations, which, together with appropriate boundary and/or initial conditions, describe the situation. These differential equations can be either ordinary (ODEs) or partial (PDEs) and finding and interpreting their solution lies at the heart of applied mathematics. This module develops the theory of differential equations with a particular focus on techniques of solving both linear and nonlinear ODEs. Fourier series, which arise in the representation of periodic functions, and special functions, which arise in the solution of PDEs such as Laplace’s equation that models the flow of potential, are also introduced. A number of the classical equations of mathematical physics are solved.

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**Module Title:**LI / LH Statistics

**Module Code:**25671 / 27147

**Semester:**2

**Credits:**20

**Level:**LI / LH

**Module Description:** Statistics is the study of uncertainty, which arises in all aspects of life. How long will I live for? What is the probability that Birmingham City will win the FA Cup this season? Will it rain today? What is the probability that I will win the lottery this week? Statistical theory and methods are fundamental to our understanding of such uncertainty, and are an increasingly sought after skill. For example, Google uses statistics to improve their search algorithms; medical research uses statistics to design and analyse clinical trials evaluating whether a new cancer treatment is effective; and actuarial and economic teams use statistics to make accurate predictions about future risks and outcomes.

This module presents a parallel development of statistical theory and methods, building on the introductory material in Probability & Statistics. Topics covered include classical linear models, with an introduction to the analysis of variance; basic methods for handling discrete data; further work in the theory of probability distributions; and some aspects of the theory of estimation and hypothesis testing. In the computing sessions, a statistical package is used to illustrate the application of statistical methods to the analysis of some typical data sets.

**Module Title:**LH Randomness and Computation

**Module Code:**31131

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LH

**Module Description:** This module comprises a selection of topics in Probability and an introduction to the foundations of the Theory of Computation. The final goal of the module is to develop a detailed understanding of the design and analysis of randomised algorithms. The module is aimed at students with interest in theoretical aspects of computing, graph theory, combinatorics, statistics or data science. Structures arising throughout the module also play important roles in other settings, for example, in stochastic models in finance.The module is structured into two parts: Randomness and Computation.

The first part of the module (Randomness) covers advanced techniques in probability theory including classical concentration inequalities, martingale theory and an introduction to random graphs. This part of the module also treats simple randomised algorithms such as randomised Quicksort. The second part of the module (Computation) provides an introduction to the Theory of Computation covering topics such as (randomised) complexity classes, P vs. NP, Las Vegas and Monte Carlo algorithms and decidability.

The module concludes with the presentation of the design and the analysis of several efficient randomised algorithms, which provide approximate solutions to computationally hard problems such as satisfiability and Max-cut. In each part of the module practical examples supplement and illustrate the theoretical concepts developed.

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**Module Title:**LH Metric Spaces and Topology

**Module Code:**27722

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1.*

**Level:**LH

**Module Description:** This module introduces metric and topological spaces as abstract settings for the study of analytical concepts such as convergence and continuity. This generalization allows one, for example, to regard functions as points of a space and to consider various ways in which the function can be the limit of other functions. Extra structure is introduced: compactness, for instance, is shown to be the proper generalization of the closed bounded intervals often used in analysis on the real line. Connectedness, completeness will also be introduced as will separation axioms, e.g. the Hausdorff property.

The course may end with some applications for example proving the existence of a function that is continuous everywhere on the real line, but differentiable nowhere. Also some methods from algebraic topology, e.g. homotopy, may be introduced.

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**Module Title:**LH Statistical Methods in Economics

**Module Code:**23062

**Semester:**1

**Credits:**20

**Level:**LH

**Module Description:** This course is designed for students with limited or no prior economic theory background. It emphasizes the understanding of quantitative methods, model evaluations, and the techniques for empirical studies in economics. This module starts with an introduction to general economic concepts, then it will cover the basics and extension of ordinary least square methods, heteroscedasticity, autocorrelation, multicollinearity, model specifications, simultaneous equation models, binary and discrete choice models, qualitative and limited dependent variable models, time series analysis, panel data models, and nonparametric analysis with their applications in Economics. Students will gain hands-on experience formulating and estimating models, interpreting results, and making forecasts.

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**Module Title:**LH Functional and Fourier Analysis (only available for full year study abroad)

**Module Code:**31129

**Semester:**Full Term

**Credits:**20

**Level:**LH

**Module Description:** The first half of this module (Functional Analysis) introduces Hilbert spaces, Banach spaces, dual spaces and linear operators, and explores the interaction between linear algebra and analysis in the study of infinite dimensional spaces. The second half (Fourier Analysis) introduces and develops the classical theory of Fourier series and the Fourier transform on the real line, with emphasis on both mathematical rigour and applications.

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**Module Title:**LH Numerical Methods and Numerical Linear

**Module Code:**33914

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LH

**Module Description:** Numerical linear algebra is the language of all scientific computing, particularly for applications arising in mathematical and engineering modelling. This module is aimed at applied mathematicians with an interest in numerical methods and more generally scientific computation. After a review of linear algebra topics and an introduction to matrix theory and computation, the module will discuss in detail methods for linear systems of equations, both direct and iterative, methods for eigenvalue problems and an introduction to fast Fourier transforms. The module will include a programming component; in particular, standard algorithmic concepts will be introduced together with notions of computational complexity and good coding practice.

Applications drawn from applied mathematics (e.g., dynamical systems, ordinary and partial differential equations etc) will be used for illustration purposes. This module will use the computer package Matlab. This module builds upon the core numerical techniques students learned in Year 2.

It further develops theoretical foundations of practical algorithms for approximating functions and data (Lagrange and Hermite interpolation, adaptive approximation), for solving systems of nonlinear equations (Newton's method and its variants, fixed-point methods), for efficient evaluation of integrals (Romberg, Gaussian, and adaptive quadratures), and for numerical solution of ordinary differential equations (Taylor series method, Runge-Kutta methods, multistep methods). Theoretical and practical aspects of numerical algorithms will be illustrated with MATLAB examples.

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**Module Title:**LH Nonlinear Programming I and Heuristic Optimisation

**Module Code:**19590

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LH

**Module Description:** Many decision problems arising in managerial decision making in the public as well as in the private sector are inherently nonlinear, and the same holds for various problems occurring in science and engineering. Tackling highly realistic nonlinear problems leads to solution methods totally different from those of linear programming. In the first part of this module essential theory of unconstrained and constrained nonlinear optimization, including optimality conditions, will be presented. Based on this, some essential solution techniques, such as gradient methods, Newton’s method, penalty, barrier and SQP methods will be introduced.

Many problems from management mathematics (discrete or continuous) are NP-hard. In other words, optimisation problems that arise in industry or in public sector could not be solved exactly in reasonable computing time, even with modern computers. Therefore, when traditional mathematics techniques fail to give fast answers, one should rely on near-optimal solution methods or heuristics. Ideas of classical heuristics (several from: greedy, constructive, A\* search, relaxation, local search, divide and conquer, dynamic programming, Lagrangean etc) will be studied first. A modern heuristic (metaheuristics) or general frameworks for building heuristics, usually gives rules of escaping from the so-called "local optima trap". Some modern heuristics, such as Genetic algorithms, Tabu search, Simulated Annealing, Variable neighbourhood search, Neural Networks, Ant Colony etc. will be presented.

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**Module Title:**LH Graph Theory

**Module Code:**19592

**Semester:**Full Term

*Also available as a 10 credit component in Semester 1.*

**Credits:**20

**Level:**LH

**Module Description:** The module will give an introduction to fundamental results and concepts in graph theory. This is an area of Pure Mathematics which underpins much of the digital economy. Topics are likely to include Hamilton cycles, graph matchings, connectivity, graph colourings, planar graphs and extremal graph problems. For example, a fundamental result in Graph Theory is Hall’s marriage theorem, which characterizes all bipartite graphs that can be split into compatible pairs. Another famous result is the four colour theorem, which states that every planar map can be coloured with at most four colours such that adjacent regions have different colours (this can be translated into a graph colouring problem and has applications to scheduling).

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**Module Title:**LH Financial Mathematics

**Module Code:**TBC

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1.*

**Level:**LH

**Module Description:** This module introduces the fundamentals of mathematical modelling in finance, and the mathematics of financial annuities and investments. We explore the use of deterministic models that can be used to model and value known cashflows. We also explore stochastic, discrete-time models of investment risk and return.

Topics include:

* Data and financial modelling
* Theory of interest rates
* Equations of Value
* Theories of financial market behaviour
* Introduction to interest rate models
* Modern portfolio theory
* Asset valuation
* Measures of investment risk

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**Module Title:**LH Integer Programming and Combinatorial Optimisation

**Module Code:**21624

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LH

**Module Description:** Many practical problems such as train and airline scheduling, vehicle routing, production planning, resource management, telecommunications and network design can be modelled as integer or mixed-integer programs.

This module presents a comprehensive theory and exact and approximate algorithms for integer programming problem and a wide variety of its applications. This module will start with formulations and illustrative examples of integer programs. Following that, the optimality, relaxation, bound and total unimodularity will be introduced. Based on these fundamental concepts, some computational methods of integer programing such as the dynamic programming, branch and bound, valid inequalities and cutting planes, and heuristic methods will be presented. Modern semi-definite programming (SDP) technique dealing with integer programming is optional and at the discretion of the lecturer in charge.

The second part of this module presents a systematic survey of methods of optimisation for problems with discrete features, and relates them to practical problems such as finding the cheapest route through a transportation network or efficiently assigning resources to objectives. The concept of computational complexity leads to a classification of problems into grades of hardness and to the concept of the efficiency of an algorithm.

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**Module Title:**LH Number Theory

**Module Code:**22498

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1.*

**Level:**LH

**Module Description:** A spectacular development in mathematics is Wiles' proof of Fermat's Last Theorem: if n>2 then xn+yn=zn has no nontrivial integer solutions. A high point of the module is a proof of Fermat's Last Theorem for n=3. Ideas relating to integer and primes are generalized to other number systems e.g. the Gaussian integers Z[i] = {x + iy | x and y integers}. An analogue of the Fundamental Theorem of Arithmetic is proved for Z[i]. Concrete numerical examples illustrate to concepts involved. Modular arithmetic is studied. The high point being Gauss' celebrated Law of Quadratic Reciprocity concerning the existence of square roots modulo a prime. Time permitting, other topics may be studied, e.g. Fermat's Last Theorem for n=5, Mersenne primes, the abc-conjecture, recent advances.

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**Module Title:**LH Applied Statistics

**Module Code:**22515

**Semester:**2

**Credits:**20

**Level:**LH

**Module Description:** This module provides an introduction to a wide range of applicable statistical techniques. A unifying theme is the transferability of statistical ideas. Common features shared by different fields of enquiry enable the development of statistical methodologies with applications throughout science, Industry and Medicine. Examples from such fields - including the rapidly developing area of Genomics - inform every aspect of the module. Topics covered which exhibit this transferability will include survival analysis, in which there are only lower bounds on some data values, muliti factor and other generalized linear models, of use when the influences of many factors must be unravelled, data mining techniques, applying when it is desired to search out relationships and, last but certainly not least, the principles and consequences of good statistically designed studies.

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**Module Title:**LH Methods in Partial Differential Equations

**Module Code:**27714

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1.*

**Level:**LH

**Module Description:** This module introduces the concept of partial differential equations, the concept of solution to partial differential equations, with initial and initial boundary value problems for evolution PDE, and steady state boundary value problems for steady state PDE. First order PDE and systems of first order PDE’s are considered (both linear and nonlinear) and solution methods are developed, with specific examples relating to linear and nonlinear simple wave PDE’s. General second order linear PDE are considered, and classified accordingly to canonical form in canonical coordinates. Second order linear hyperbolic, parabolic and elliptic PDE’s are examined in general, and then in detail for the wave equation, the diffusion equation and Laplace’s equation. More general linear evolution PDE will also be considered. The solution methods with involve Fourier integral, Fourier series and Green’s Function approaches. Uniqueness will be established in all cases. Specific nonlinear evolution PDE such as the Burger’s equation and Korteweg de Vries equation will be introduced and discussed.

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**Module Title:**LH Advanced Mathematical Modelling

**Module Code:**33917

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1.*

**Level:**LH

**Module Description:** Mathematical models are used increasingly to understand complex phenomena in biology and medicine, and have been used to explain phenomena at a wide range of scales, from genes, proteins and metabolites, cells, tissues and organs, to organisms, populations and ecosystems. This module builds on the students’ knowledge of mathematical nonlinear differential and difference equations to explore the paradigm models in mathematical biology, particularly microbiology and developmental biology.

The mathematical models will be linked to experimental work and biomedical science, in particular focusing on the importance of experiment in testing and refining models, in estimating parameters, and finally the application of models in making useful predictions. Topics will cover a broad spectrum of population dynamics models to be selected from predator-prey systems, enzyme kinetics, population genetics, chemical signalling, gene regulation networks, epidemiology and neuron firing.

Partial differential equations describe a vast array of phenomena in nature, engineering and industry, whenever there are systems which vary in more than one dimension, e.g. space and time. Students will be introduced to a range of paradigm models from elasticity, fluid mechanics, heat transfer, chemistry, electromagnetism and traffic/crowd modelling, in many cases motivated by problems of industrial interest. A unifying theme will be the role of conservation laws in motivating models. Mathematical approaches to dimensional analysis, steady state and asymptotic simplification will be covered, in addition to analytical solutions where possible.

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**Module Title:**LH Combinatorics and Communication Theory

**Module Code:**19601

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LH

**Module Description:** The first part of the module will give an introduction to several combinatorial structures, which have applications in different areas. Topics are likely to include combinatorial games, applications of counting principles to discrete probability and basic Ramsey theory. (Here Ramsey theory can be viewed as a formalization of the notion that ‘complete disorder is impossible’ - this surprising phenomenon will be investigated for graph colourings and arithmetic properties of the integers).

The second part of the module consists of an introduction to information theory and coding theory. The aim here is to transmit information (i) efficiently and (ii) reliably over a noisy channel. For (i), the main result will be Shannon’s noiseless coding theorem, which relates coding efficiency to the entropy of a source. For (ii) we will discuss error correcting codes, including several linear codes, such as Hamming codes. Both parts of the module are linked by the methods and ideas that are used.

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**AVAILABLE IN S1**

**Module Title:**LH Group Theory

**Module Code:**29727

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1.*

**Level:**LH

**Module Description:** Group theory is the mathematical study of symmetry. In this course groups and their actions on sets, and geometric structures will be studied. A highlight of this course is Sylow's Theorem, which is probably the most fundamental results about the structure of finite groups. Finite simple groups are the building blocks from which all finite groups are built (the Jordan-Holder theorem makes this statement precise) and these will be studied. The alternating groups and linear groups will be introduced as first examples of non-abelian simple groups. Later in the course field automorphisms may be considered so that an overview of Galois Theory can be given.

**Module Title:**LH Game Theory and Multicriteria Decision Making

**Module Code:**32281

**Semester:**Full Term

**Credits:**20

*Also available as a 10 credit component in Semester 1 or in Semester 2.*

**Level:**LH

**Module Description:** The first half of this module presents game theory as the study of decision-making in competitive situations. It provides an introduction to the theory of finite and infinite games with a particular emphasis on 2-person games. All results will be presented in a rigorous way and accompanied, wherever possible, by showing economic applications. This module also demonstrates that the results and concepts of other branches of mathematics (like the fixed point theorem, convexity, duality) have practical interpretation and use.

The second half of this module explores multicriteria or multiobjective optimisation where several conflicting objectives have to be optimised simultaneously: stock portfolios have to be chosen such that the portfolio maximises the return and simultaneously minimises the risk; health care has to be managed such that the service is efficient yet not too costly; hazardous material has to be transported such that risk as well as costs incurred are minimal; bridges and buildings have to be designed such that they can be built cheap but still with maximum stability etc. As such, multicriteria problems are of prime importance for decision makers in the private as well as the public sector. This module brings together various ideas from geometry and analysis in studying solutions and solution methods for multicriteria problems in management and science.