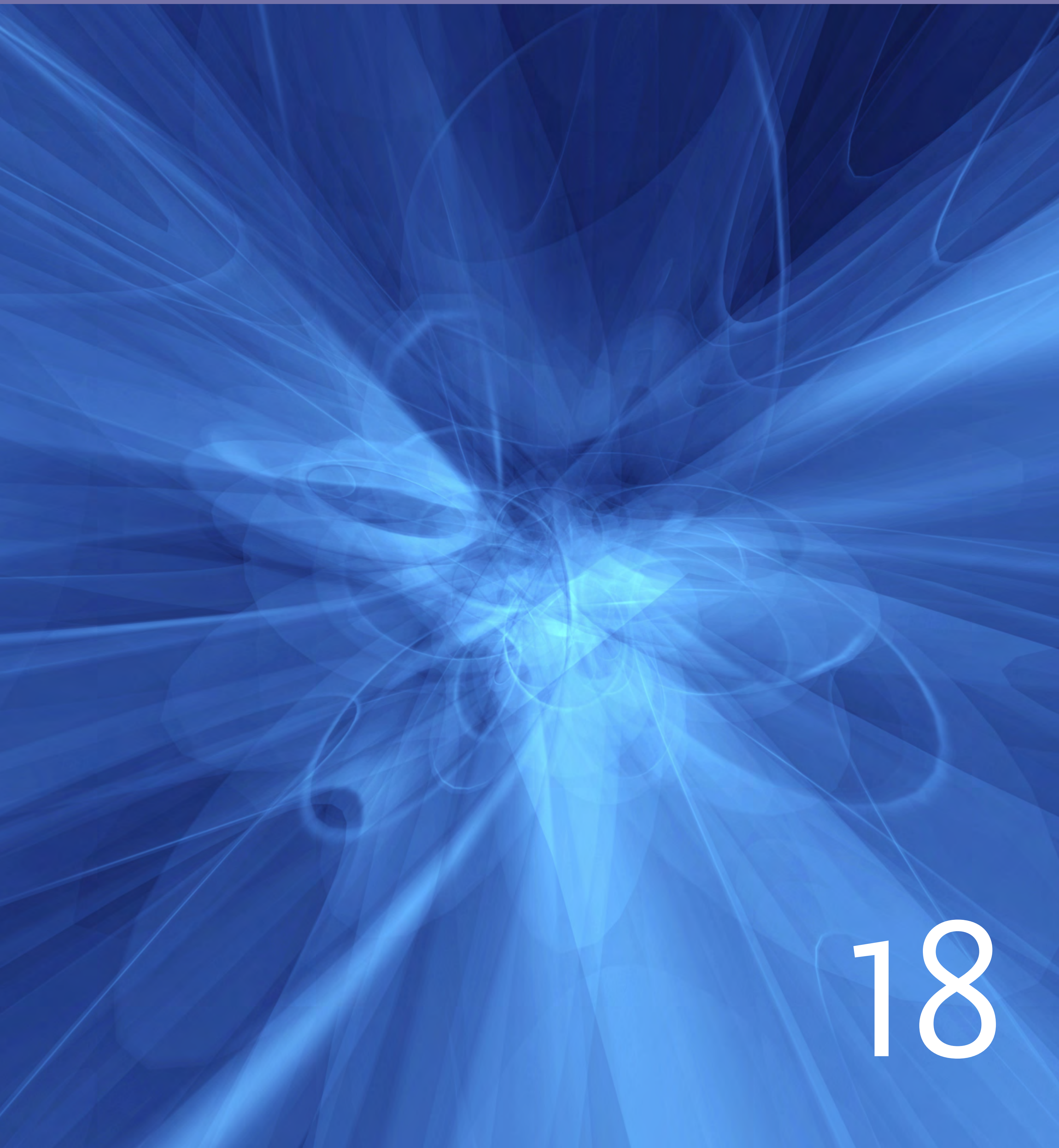
School of Mathematics and Statistics
College of Engineering

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Postgraduate Handbook 2018



School of Mathematics and Statistics

Postgraduate Programme 2018

Welcome from our School. Postgraduate study enables you to study selected mathematical and statistical topics in depth. There is a change of emphasis from the preceding undergraduate years: courses tend to be more focused on a specific problem or class of problems, rather than attempting to give a broad coverage of a branch of mathematics and statistics.

There is the possibility of taking one or more projects in which you investigate some problem with the assistance of a member of staff. Depending on the nature of the problem, this may involve literature searches, the use of various computing packages (for example `MATLAB`, `Maple` or `R`), resources on the internet, proving new theorems or data analysis. You will produce a written dissertation and may give an oral presentation.

Any proposed programme of study requires the approval of the 400 level coordinator. It is highly unlikely that any proposed programme that has a high workload in one semester will be approved, so you should try to construct a programme that balances your workload evenly over both semesters.

You can include some courses from other subjects (e.g. COSC480 is recommended for developing programming skills). This is a good way to ensure you have a broad program of study. Check with the School's 400 level coordinator that the courses from other subjects are suitable for inclusion within your program of study. In addition, there are a various joint programs between our School and other Departments/Schools detailed below.

At the Masters and PhD level you will undertake research, often focussed on deep study of a specialised topic. You will learn skills in undertaking systematic investigations, contextualising your work within the current state of understanding, so that your research outcomes can extend beyond the forefront of human knowledge.

Honours or PG Diploma in Mathematics/Statistics?

The School offers both Honours and Postgraduate Diploma programs of study, which can be undertaken under Science or Arts. The most appropriate program is best decided on a case-by-case basis which you should discuss with the 400 level Coordinator, Dr Mark Hickman. The following guide provides some general advice about your options. You are welcome to get in touch as soon as possible, but you must do so before the formal enrolment period. If you are undertaking honours, you must have arranged a supervisor of your project in advance of enrolment. The 400 level coordinator can help you with this.

In addition, we also offer a Postgraduate Certificate in Arts for students interested in a 60 points programme of study, or a Certificate of Proficiency for undertaking a course or courses of interest.

Who should think about Honours? If you view Mathematics/Statistics as more than a means to an end, then doing Honours will be a year well spent. In addition to taught courses, the honours program has a full year 30 point project which will not only deepen your understanding of a specialised topic but will also develop many of the soft skills desired by employers or for further Postgraduate study, like self-motivation, independent learning, research, written and oral communication.

The Honours subject majors are listed below. Formal details are in the UC Calendar. To enter Honours in Mathematics, you will need at least 60 points from MATH301-394, plus at least 30 points from 300-level MATH, STAT or other approved courses. For Honours in Statistics, you need at least 60 points of 300-level STAT301-394, plus at least 30 points from 300-level STAT, MATH or other approved courses. Normally you will have maintained at least a B+ average in these papers.

BSc (Hons) Major Subjects

In the Science faculty, Honours from our School may be completed in:

- Mathematics and/or Statistics, see Dr. Mark Hickman;
- Data Science; see Prof. Jennifer Brown;
- Mathematical Physics, see Assoc. Prof. Jenni Adams (Physics);
- Computational and Applied Mathematical Sciences, see Assoc. Prof. Rick Beatson;
- Mathematics and Philosophy, see Assoc. Prof. Clemency Montelle;
- Finance and Mathematics, see Assoc. Prof. Rua Murray;
- Finance and Statistics, see Assoc. Prof. Marco Reale; or
- Financial Engineering, see Assoc. Prof. Marco Reale.

These Honours programs typically require completion of papers totalling 120 points at 400 level or above (typically eight 15 point courses), as well as a 30 point MATH/STAT/CAMS449 project. In the case of data science, the project is 45 points.

BA (Hons) Major Subjects

In the Arts faculty, Honours from our School may be completed in Mathematics or Statistics. Subject to CUAP approval (due December 2017), BA (Hons) consisyes of a project (MATH/STAT449) and six papers (120 points in total).

Who should think about a Postgraduate Diploma? The Postgraduate Diploma can consist entirely of taught courses, as there is no requirement that any project is undertaken. The entry requirements are as for Honours, except that you are not required to have a B+ average. It is very strongly recommended that your average grade in your majoring subject at stage 3 is at least a C+. The PGDipSc can also be used as Part I of a two part research MSc.

PGDipSci and PGDipArts Major Subjects

In both the Science and Arts faculty the Postgraduate Diploma can be taken in mathematics or statistics. In addition a Postgraduate Diploma in data science may be taken in the Science faculty. These diplomas require completion of papers totalling 120 points at 400-level or above (typically eight 15 point courses).

Masters in Applied Data Science

Data science is a new profession emerging along with the exponential growth in size, and availability of 'big data'. A data scientist provides insight into future trends from looking at past and current data. Data science is an essential skill in a world where everything from education to commerce, communication to transport, involves large scale data collection and digitalisation. New Zealand and other countries are currently experiencing a skills shortage in this area, and the need for data savvy professionals with applied experience is growing.

This 180 point conversion master's is designed to accommodate students from a range of undergraduate backgrounds (not just those with Mathematics, Statistics and Computer Science majors), who want to enhance or build their data science capabilities and combine these with the skills and knowledge they bring from their previous studies. So long as you are data-hungry and industry-aware; this degree can add to your employability and career prospects.

Masters in Financial Engineering

Financial engineering is a cross-disciplinary field combining financial theory, mathematics, statistics and computational tools to design and develop new financial or actuarial products, portfolios and markets. It also has an important role to play in the financial industry's regulatory framework. Financial engineers manage financial risk, identify market opportunities, design and value financial or actuarial (insurance) products, and optimize investment strategies.

The year long 180 point program consists:

- 135 points from taught courses. There is a core set of required courses in finance, mathematics & statistics and computer science. Further, there are a suite of suggested courses from these topic areas, that make up the majoring subject of Financial Engineering. Depending on your prior education, it is envisaged that around half of the taught courses will be MATH400 or STAT400 papers and the other half will be FINC600 papers; and
- the 45 point paper FENG601 Application of Financial Engineering which provides the opportunity to apply the techniques learned through the programme to real-world financial engineering problems.

There are minimum entry requirements into the program, which if not met you will be required to take FIEC601 in January-February prior to commencement of the program proper. You will be required to complete COSC480 Introduction to Programming, if you do not have equivalent programming skills (e.g. from COSC121, MATH170, EMTH171 or STAT221). Full details are provided in the UC Calendar.

Research Masters

A research Masters in Science (MSc) or Arts (MA) consists of two parts:

- Part I - a 120 points of papers (typically eight 15 point courses); and
- Part II - a 120 points research thesis.

Students can enter directly to Part II, if they have completed a Postgradute Diploma or Honours degree in the same majoring subject. For full details see the UC Calendar.

Our School offers the research MSc and MA in mathematics or statistics. An MSc is also offered in computational and mathematical sciences and data science. Enrolment in a Master's programme requires approval from the Postgraduate Coordinator, Dr Miguel Moyez-Gonzalez. At least one staff member must have agreed to supervise your Part II research study before approval of your programme of study.

PhD Research

The PhD programme is the highest degree offered in UC. How do you know if you are ready to purse a PhD in any of the following subjects we offer?

- mathematics;
- statistics;
- computational and applied mathematical sciences (CAMS);
- mathematical physics; and
- mathematics and philosophy.

The simplest answer is: if you are passionate about a subject and you want to get a deeper understanding of a field of study or want to use sophisticated tools from mathematical sciences to solve real world problems, then you are ready!

If you want to upscale your knowledge in the subject you love then a PhD in mathematics or statistics is the programme for you. On the other hand, if you have an interdisciplinary project in mind then a PhD in CAMS could be a good option for you.

Further details are available from the PG Office website, including scholarship information, here: `http://www.canterbury.ac.nz/postgraduate/phd-and-doctoral-study/` Excellent performance in a BSc (Hons) or BA (Hons) may provide sufficient training to undertake a PhD, thus obviating the need for a Masters degree. However, a PGDipSc or PGDipArts would not normally be sufficient.

400-LEVEL COURSES

The proposed courses for 2018 are outlined in this booklet. The final decision about which courses are to be offered will depend on the availability of staff and on student interest. The School reserves the right to cancel any course that does not attract four or more students, which will be determined at the beginning of each semester.

It is also possible (and often desirable) to include courses from other subjects, see the Regulations in the Calender for details with each degree. Note that any STAT courses may be included in a Mathematics degree and vice versa.

Some of our 400-level courses are dual-coded with the corresponding 300-level courses for which those on offer in 2018are:

- MATH439/MATH321 Rings and Fields;
- MATH433/MATH380 Mathematics in Perspective;
- MATH443/MATH343 Metric, Normed and Hilbert Spaces;
- MATH414/MATH353 Computational Methods/Computational Mathematics and Applications;

- STAT455/STAT312 Data Collection and Sampling Methods;
- STAT461/STAT314 Bayesian Inference;
- STAT463/STAT315 Multivariate Statistical Methods;
- STAT456/STAT317/ECON614/ECON323 Time Series and Stochastic Processes;
- STAT462/STAT318 Data Mining; and
- STAT446/STAT319 Generalised Linear Models.

On these dual coded courses, you will attend the same lectures and tutorials/labs as the 300 level students, but will be assigned additional coursework and assessment to achieve the NZQF Level 8 standard. Students who have done, or are doing, the 300-level course cannot do the corresponding 400-level course.

Mathematics

MATH401 **15 points**
Dynamical Systems 1
MATH401-18S2 (C)

Dynamical systems sits at the interface of pure an applied mathematics, containing some beautiful theory, as well as applications in diverse fields including numerical analysis, biological systems, economics and medicine.

It is often difficult or impossible to write down an exact solution to systems of nonlinear equations. The emphasis in this course will be on qualitative techniques for classifying the behaviour of nonlinear systems, without necessarily solving them exactly. Two main types of dynamical systems will be studied: discrete systems, consisting of an iterated map; and continuous systems, consisting of nonlinear differential equations.

Topics covered will include: bifurcations and chaotic behaviour of interval maps; symbolic dynamics; topological model of chaos; mass transport and probabilistic dynamics; phase portrait analysis (Hartman-Grobman theorem, hyperbolicity of limit cycles, invariant manifolds, global bifurcations); centre manifolds.

This course is independent of MATH363 Dynamical Systems, although previous enrolment there is desirable.

Enquires: Rua Murray

MATH407 **15 points**
Special Topic - Stochastic Processes
MATH407-18S2 (C)

The theory and application of stochastic processes.

Term 3 (Michael Plank): probability theory, continuous random walks, Poisson and pure-birth processes, Markov processes.

Term 4 (Mike Steel):, random graphs, probabilistic method, information theory, branching processes, Polya-urn models, Martingales

Enquires: Michael Plank and Mike Steel

MATH411 **15 points**
Topics in Algebra
MATH411-18S1 (C)

The focus of this course is Galois theory, which provides a beautiful connection between field theory and group theory. It can be used to reduce certain problems about fields to group theory which is, in some sense, simpler and better understood. Topics in the theory of finite groups will be covered as needed. Goals of the course include proofs of the Abel-Ruffini Theorem (concerning insolubility of a general quintic equation by radicals) and the Fundamental Theorem of Algebra. Useful prerequisites are MATH240 or MATH321, and ideally both.

Enquires: Brendan Creutz

MATH412 **15 points**
Unconstrained Optimization
MATH412-18S1 (C)

This course looks at unconstrained and constrained local minimisation of functions of several variables. The focus is largely on gradient based methods including steepest descent, Newton, quasi-Newton and conjugate gradient methods. Constrained methods include augmented Lagrangian and sequential quadratic programming techniques. Direct search methods in global optimisation will also be looked at. These have the advantage of not relying on the availability or even existence of derivatives, at the cost of a reduction in speed.

Enquires: Chris Price

MATH414 **15 points**
Computational Methods
MATH414-18S1 (C)

This course looks at a variety of algorithms for solving important computational problems that arise in science, engineering, and commerce. Topics covered include an introduction to the numerical solution of partial differential equations, and numerical methods for the eigenvalue problem. Other topics include the Fast Fourier Transform, and numerical approximation techniques. See MATH353.

Enquires: Miguel Moyez-Gonzalez

MATH416 **15 points**
Exterior Differential Systems
MATH416-18S1 (C)

Moving frames and exterior differential systems form a natural backdrop for the study of problems in geometry and partial differential equations. In particular, most (if not all) physical systems exhibit symmetry and so embody geometric content in the differential equations that describe the physics. These systems are naturally described in the coordinate free approach of moving frames. Integrability conditions, the "size" of the solution space and the existence of "singular" branches of the solution space for systems of partial differential equations can be readily found in the moving frame approach.

This course will introduce moving frames and exterior differential systems with an emphasis on the conceptual and operational issues. The "standard" vector calculus will be revisited with the aid of differential forms. Their application to simple geometric problems and the reformulation of Maxwell's equations as an exterior differential system will be considered. If time permits (and depending on student interest) either the exterior differential system formulation of Einstein's field equations or application of moving frames to computer recognition of objects will be considered.

Prospective students should have familiarity with partial differential equations and vector calculus.

Enquires: Mark Hickman

MATH420 15 points
Hilbert Spaces
MATH420-18S2 (C)

The theory of Hilbert spaces is fundamental in many areas of modern mathematical analysis, having a clear and easy-to-grasp geometric structure, just like Euclidean spaces. However, unlike Euclidean spaces, Hilbert spaces may be infinite dimensional. The course will be self-contained, introducing important spaces (especially L2(m)), operators on them, and basic spectral theory. Prior exposure to MATH343 would be an asset, but is not mandatory.

Enquires: Hannes Diener

MATH426 15 points
Differential Geometry
MATH426-18S1 (C)

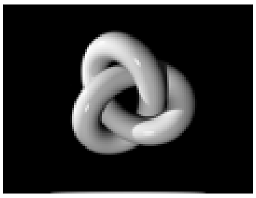
Have you ever wondered why you can roll a piece of paper into a tube but cannot bend the paper tube to form a torus without wrinkling or breaking the paper or how a Ôflat beingÕ can decide whether it lives on a 2-sphere or a torus? There are physical reasons to the first question but differential geometry also provides a mathematical answer to both.

The principal objects of interest in differential geometry are differentiable manifolds, like a sphere or a torus, that may be equipped with additional structures, like a metric or a group structure, which leads to Riemannian geometry or Lie groups, respectively. One then investigates intrinsic properties of differentiable manifolds and their invariants. In so doing one encounters many ideas which are not only beautiful in themselves but are basic for both advanced mathematics and theoretical physics.

The course gives an introduction to classical differential geometry including the basic theory of manifolds, vector fields, geodesics and intrinsic invariants like curvature, and how Lie groups feature in this context.

Enquires: Gunter Steinke

MATH428 **15 points**
Topology
MATH428-18S2 (C)



Topology, colloquially known as "rubber-sheet geometry", is the study of continuity in an abstract setting. Topological notions underpin, or are used in, many areas of mathematics, both pure and applied. In this course, we study some of the main concepts of point set topology, and provide a brief introduction to algebraic topology.

The topics will cover: Metric and topological spaces; continuous functions and homeomorphism; compact and connected spaces; quotient and product topology; surfaces, manifolds and knots; homotopy, the fundamental group and applications.

Recommended texts:
Topology, Klaus Jänich, Springer-Verlag, 1984
Basic Topology, M. A. Armstrong. Springer, 1983.
Renzo's Math490, .pdf available online.

Assessment:
Two assignments, each worth 20% Final exam, worth 60%

Enquires: Mike Steel

MATH429 **15 points**
Combinatorics
MATH429-18S1 (C)

Matroids (combinatorial geometries) are precisely the structures that underlie the solution of many combinatorial optimisation problems. These problems include scheduling and timetabling, and finding the minimum cost of a communications network between cities. Matroid theory also unifies the notions of linear independence in linear algebra and forests in graph theory as well as the notions of duality for graphs and codes. This course is an introduction to matroid theory and is designed for mathematics and computer science students.

Enquires: Charles Semple

MATH433 **15 points**
Mathematics in Perspective
MATH433-18S1 (C)

What is Mathematics? What are some of the key moments in the history of Mathematics? What kinds of mathematical result are considered important, and why?

This course is about the history, philosophy, people and major results of Mathematics over the centuries. Since we will minimise the attention paid to technical details, the course should be accessible not only to those with a 200 level Mathematics background, but also to intellectually mature students in Philosophy and related subjects. In particular, it is strongly recommended for anyone who intends teaching Mathematics at any level from primary school onwards.

See MATH380.

Enquires: Clemency Montelle

MATH439 **15 points**
Rings and Fields
MATH439-18S1 (C)

This course formally introduces rings and fields, which have been encountered at 100- and 200-level in special situations, and investigates their algebraic structure.

It gives a deeper understanding of these algebraic concepts and thus provides a thorough grounding in the algebraic theory which underpins modern applications like cryptography, error-correcting codes, number theory or finite mathematics. If you are interested in any of these subjects or if you want to see how algebraic theory can be applied to solve certain geometric construction problems or prove their impossibility, then this is the course to take.

See MATH321.

Enquires: Gunter Steinke

MATH440 **15 points**
Graph Theory
MATH440-18S2 (C)

In a nutshell, graphs are mathematical structures which model relationships between objects. Graph theory is the branch of combinatorics concerned with their study, and has grown to become a very rich and diverse discipline in its own right. It has applications in almost every scientific field, from analysing the spread of epidemics, to modelling social networks. This is a self-contained advanced-level graph theory course, which explores some of the most important results in the field.

The course is intended for students majoring in Mathematics or Computer Science. (Does not require MATH120 or MATH220.)

Enquires: Jeanette McLeod

MATH442 **15 points**
Special Topic - Number Theory
MATH442-18S2 (C)

Number Theory is the study of properties of the integers. Building on only basic knowledge of prime factorisation and modular arithmetic (from MATH120) we will study further properties of the whole numbers. The course will cover the following topics: Solutions of quadratic congruences, quadratic residues and the quadratic reciprocity law. The latter relates the question of whether p is a square mod q to whether q is a square mod p, for primes p and q and is a pivotal result that has motivated a lot of modern number theory. Representation of integers as sums of squares, in particular weÕll prove Fermat's theorem that primes congruent to 1 mod 4 are a sum of two squares and Lagrange's theorem that every integer is a sum of four squares. We will also study quadratic Diophantine equations in some generality. We will also begin the study of cubic equations and elliptic curves.

Enquires: Felipe Voloch

MATH443 **15 points**
Metric, Normed and Hilbert Spaces
MATH443-18S1 (C)

This course introduces those parts of modern analysis that are essential for many aspects of Pure and Applied Mathematics, Physics, Economics, Finance, and so on. For example, if you want to understand the convergence of numerical algorithms, approximation theory, quantum mechanics, or the economic theory of competitive equilibrium, then you will need to know something about metric, normed and Hilbert spaces.

See MATH343.

Enquires: Hannes Diener

MATH444 **15 points**
Special Topic – Mathematics of the Physical World
MATH444-18S1 (C)

“The great book of nature", wrote Galileo, "can be read only by those who know the language in which it was written. And this language is mathematics." Doing good science means doing good mathematics, and applied mathematics is the common language of modern interdisciplinary teams of scientists. This course will be an introduction to the foundational areas of applied mathematics which are used to solve problems in biology, aeronautics, medicine, industry, and pure science, and will cover key techniques and theorems. The course is suitable for mathematics students who enjoy both rigour and applications, and to science students with an interest in mathematics. A background in analysis or PDEs is recommended.

Enquires: Miguel Moyers-Gonzales and Phil Wilson

MATH449 **30 points**
Project
MATH449-18W or CY (C)

A whole year research project in mathematics (see Honours projects).

Enquires: Mark Hickman

MATH475 **15 points**
Independent Course of Study
MATH475-18S1 or S2 (C)

This course allows a student to perform directed reading of a particular topic under a Mathematics lecturer. The topic choice is by mutual arrangement with the lecturer. Students should ensure these arrangements are in place before enrolling in the course.

Enquires: Any mathematics Lecturer

MATH491 **15 points**
Research Project
MATH491-18SU2 and A (C)

This 150 hour course provides students with an opportunity to develop mathematical or statistical research skills to extend and strengthen their understanding of an area of mathematics or statistics. Students will be involved in a research project with a supervisor. The project will be closely aligned with the supervisor’s existing research programme.

The research project cannot be used towards your degree requirements, but does contribute to your GPA.

Enquires: Alex James or Michael Plank

Statistics

STAT445 **15 points**
Financial Time Series
STAT445-18S1 (C)

In many applications, in particular in finance and economics, observed data series often exhibit a behaviour which cannot be modelled with linear time series models (i.e. ARMA processes). Thus alternative models allowing for a nonlinear behaviour are called for and are successfully used. For instance, Robert Engle was awarded the Nobel Prize in 2003 for introducing the so-called (G)ARCH model. In this course we will first review some materials on linear time series methods, then consider and analyse several classes of nonlinear time series models, such as GARCH, Markov-switching as well as threshold autoregressive time series models. We study their common probabilistic and statistical concepts and theory (Markov chains with uncountable state space, stochastic recurrence equations, ergodicity and mixing). Finally, we will derive and apply estimators for the model parameters.

STAT445 course is required for the BSc (Hons) in Financial Engineering.

Enquires: Marco Reale

STAT446 **15 points**
Generalised Linear Models
STAT446-18S1 (C)

STAT319 and STAT446 are courses in Generalised Linear Models (GLM), suited to anyone with an interest in analysing data. In these courses we introduce you to the components of GLM and other advanced data analysis techniques. We cover analysis of data from continuous distributions, models for binomial response data, models for count response data and models for multinomial data. `R` is the free-ware equivalent to `S-Plus`, and is becoming the preferred computer package for many statisticians. In these courses we will show you how to use the package, enter, manipulate and analyze data in `R`. Suited to anyone with an interest in analysing data.

Enquires: Jennifer Brown

STAT447 **15 points**
Official Statistics
STAT447-18S2 (C)

This course provides an overview of the key areas of Official Statistics. Topics covered include data sources (sample surveys and administrative data); the legal and ethical framework of official statistics; an introduction demography; the collection and analysis of health, social and economic data; data visualisation including presentation of spatial data; data matching and integration; the system of National Accounts.

STAT447 is co-taught via our School's video-conference facilities between experts at NZ universities.

Enquires: Jennifer Brown

STAT448 **15 points**
Big Data
STAT448-18S1 (C)

STAT448 is suited to anyone with an interest in data, and how it can be used in decision making. In this course we introduce you to big data and some of the techniques you can use to access, explore and investigate it. Students enrolling in this course should be familiar with statistics and with programming.

STAT448 is co-taught via our School's video-conference facilities between experts at NZ universities.

Enquires: Jennifer Brown

STAT449 **30 points**
Project
STAT449-18W (C)

A whole year research project in Statistics (see Honours projects).

Enquires: Elena Moltchanova

STAT450 **15 points**
Advanced Statistical Modelling
STAT450-18S1 (C)

This course provides an introduction to a range of statistical techniques used in the analysis of spatial data. It will cover the basic concepts and techniques of spatial data analysis (SDA) and provide a wide range of applications examples from various fields such as geology, demographics, epidemiology and environmental sciences. A comprehensive lab programme uses a variety of software packages (including `ArcGIS`, `Geoda`, `geoR` and `WinBUGS`) to explore and analyse spatial data using the techniques taught in the course.

STAT450 is dual coded with GISC404.

Enquires: Elena Moltchanova

STAT455 15 points
Data Collection and Sampling Methods
STAT455-18S1 (C)

STAT312 and STAT455 are courses in survey methods, concentrating mainly on sample designs. The course is designed to give students an understanding of how to select samples from various types of populations of varying characteristics and produce population estimates along with measures of uncertainties in those estimates. Also you will gain some insights in the practical applications of the design of survey collections.

Richard Penny, one of the lecturers for this course, has worked for many years designing samples and surveys for Statistics New Zealand.

Enquires: Blair Robertson

STAT456 15 points
Time Series and Stochastic Processes
STAT456-18S2 (C)

STAT317/ECON323 and STAT456/ECON614 are courses in Time Series Analysis. These courses introduce to the analysis of repeated observations over time, a type of data extremely common in every discipline.

These courses are suited to anyone with an interest in analyzing data. We cover a wide range of topics, from the basic decomposition of a time series to advance topics such as spectral analysis. The methods explained during the lectures are complemented by practical computer lab tutorials which make use of the software `R`, one of the preferred computer packages by many statisticians. In these courses we will show you how to use the package, enter, manipulate and analyze time series data in `R`.

Enquires: Marco Reale

STAT460 15 points
Extreme Value Statistics
STAT460-18S1 (C)

This course aims to develop the theory and methods for modelling the extremes of random processes. Extreme value theory moves away from more traditional statistical techniques where the aims are to model the usual (or in some sense average) behaviour, to consider the unusual or rare events. It has received wide application in many fields where the risk associated with rare events are of concern, e.g. finance/economics, hydrological modelling, climate change, engineering (structural design) and material science (material fatigue/failure).

The course will cover the mathematics underlying extreme value models, statistical inference using likelihood and applications to real data, with implementation in the software package R. Recommended preparation includes second year Statistics (preferably STAT214) and at least full first year Mathematics (MATH103 or EMTH119 or equivalent).

Enquires: Carl Scarrott

STAT461 **15 points**
Bayesian Inference
STAT461-18S2 (C)

STAT314 and STAT461 introduce the Bayesian approach to Statistics using elementary parametric models and inference problems. Usually, these are the Bernoulli, Poisson, normal and linear regression models used in problems such as parameter estimation, hypothesis testing, model selection and prediction. Some comparisons with results from the frequentist approach, will be made to illustrate similarities and differences between the two approaches.

Enquires: Elena Moltchanova

STAT462 **15 points**
Data Mining
STAT462-18S1 (C)

STAT318 and STAT462 are courses in statistical learning and data mining, suited to anyone with an interest in analysing large datasets. The courses will introduce a variety of statistical learning and data mining techniques for classification, regression, clustering and association purposes. Possible topics include, classification and regression trees, random forests, A-priori algorithm, FP-growth algorithm and support vector machines. The lectures will be supplemented with laboratory sessions using the statistical software package `R`.

Enquires: Blair Robertson

STAT463 **15 points**
Multivariate Statistical Methods
STAT463-18S1 (C)

STAT315 and STAT463 are courses in multivariate statistical methods. Multivariate statistical methods extract information from datasets which consist of variables measured on a number of experimental units. Due to the large memory capacity available and with the advent of computing power, these methods are now widely applied in a variety of fields, including bioinformatics, epidemiology, finance and marketing.

The course will cover the theory and application of various multivariate statistical methods, namely: multiple regression, principal component analysis, factor analysis, discriminant analysis, and clustering methods.

It will also introduce the statistical analysis software `SAS`, which is a powerful tool when dealing with large multivariate datasets. `R`-syntax will also be briefly explained. Special attention will be given to practical applications and the interpretation of the results.

Enquires: Carl Scarrott

STAT465 **15 points**
Advanced Data Analysis and Statistical Consulting
STAT465-18S2 (C)

In most undergraduate courses, you are taught the theory behind a method and then given neat examples to which it can be applied and software to apply it. In reality, the most common question you will hear from a non-statistician is 'how do I analyse my data? So you are the one who has to come up with the appropriate research question and choose the suitable method (and sometimes learn it quickly too) . It is common in real world applications for the experiments have not been well planned and for data to be missing, which will need to be taken it into account. The assumptions underlying the statistical model (e.g. homoscedasticity and normally distributed) often do not hold and you will have to know what to do. Finally, your fellow scientists, laymen and policy-makers are all interested in different aspects of the research question and that is rarely the statistical significance of your ANOVA: you have to know how to communicate your results clearly, correctly and efficiently and how to defend your choices in data analysis and collection.

This course is about the reality of being an applied statistician. Besides covering the above points in class, individual statistical consulting session will provide you with hands-on experience.

Good knowledge of multivariate statistical methods, GLMs, and basic sampling theory expected. Working knowledge of `R` is recommended.or forecasting methods. It provides extensive training in forcasting and modelling techniques such as smoothing, dynamic regressions, multivariate autoregressions, state space models, and neural networks with a wide range of applications.

Enquires: Elena Moltchanova

STAT475 15 points
Independent Course of Study
STAT475-18S1 or S2 (C)

This course allows a student to perform directed reading of a particular topic under a Statistics lecturer. The topic choice is by mutual arrangement with the lecturer. Students should ensure these arrangements are in place before enrolling in the course.

Enquires: Any Statistics Lecturer

STAT478 15 points
Special Topic - Data Science Computing
STAT478-18S1 or S2 (C)

This course will introduce students to new computational methods used in data science. We will look at methods for data from a range of contexts, including scalable methods used for big data and distributed computing. We will cover topics primarily in cloud computing, distributed computing, and machine learning. This is a very hands on course, with students learning and experimenting on the School data science cluster. We will work in the computer lab, and students will have access to the cluster at any time to pursue additional projects.

The intent of the course is to provide an environment that is similar to what you will experience in a data science position in the real world, and to teach you to think carefully and to apply the appropriate tool for the task at hand.

Enquires: James Williams

STAT491 15 points
Research Project
STAT491-18SU2 or A (C)

This 150 hour course provides students with an opportunity to develop statistical and data science skills to extend and strengthen their understanding of a research or application. Students will be involved in a research or industry project with a supervisor. A research project will be closely aligned with the supervisorÕs existing research programme. An industry project can involve an internship, or work placement. This course cannot be used towards mathematics or statistics degree requirements, but does contribute to your GPA. For some students this course can be used for data science and applied data science degree requirements.

Enquires: Alex James or Jennifer Brown

Data Science

DATA401 **15 points**
Statistics
DATA401-18S1, S2 or SU (C)

This course covers the development of statistical concepts and their application to complex systems. This course is one of the foundation courses that applied data science students may be required to enrol in.

Enquires: Jennifer Brown

DATA449 **45 points**
Project
DATA449-18W or CY (C)

A whole year research project in data science.

Enquires: Jennifer Brown

DATA471 **15 points**
Special Topic - Digital Humanities in Data Science
DATA471-18S1 (C)

Digital Humanities brings digital tools and methods to the study of culture and society. This course covers key computational methods used in digital humanities research, namely text mining for content analysis and network analysis and visualisation, as well as covering issues in research data management and ethics. The course is taught through a combination of practical workshops, lectures and group discussion.

Enquires: Chris Thomson (Digital Humanities)

400-Level Projects

A broad range of possible projects are outlined below. However, this list is not exhaustive and other possibilities for projects are certainly possible. Project supervision is by mutual agreement of the supervisor and student. You should arrange your project by the end of the first week of term in 2018. It is suggested that you seek out possible supervisors before enrolment week.

You will hand in a written report on September 20 2018, which will contribute 80% of the grade; the remaining 20% will be an oral presentation in Term 4.

Projects in Mathematics

Novel methods for connecting orbits
Rua Murray

Many complex behaviours in dynamical systems can be explained but the existence of homoclinic orbits, or heteroclinic connections between fixed points and limit cycles. Unfortunately, such orbits tend to be “unstable" and are notoriously difficult to compute. This project will apply ideas from ergodic theory and open dynamical systems to investigate a novel computational strategy for identifying these objects.

Sudoku's and geometry over the integers modulo 3
Geertrui Van de Voorde

A solution to a Sudoku puzzle consist of an array of 9 rows and 9 columns such that in every row and every column, as well as in every of the nine 3x3 subsquares, we find exactly one of the symbols 1 to 9. Such a filled in puzzle is called a Sudoku square.

In this project, we look at ways of constructing Sudoku squares using geometry over the integers modulo 3; the coordinates of the points are taken in $\mathbf{Z}_3$. Depending on your interest, several further pathways are possible. Connections can be made with perfect error-correcting codes over the integers mod 3, or you can investigate the connection with MOLS (mutually orthogonal latin squares) by superimposing Sudoku squares, extend the notion of Sudoku to more general puzzles ($n \times n$ puzzles, 3D, different shapes), ...

Axiomatic planes
Geertrui Van de Voorde

In the real (Euclidean) plane, we know that there is exactly one line through two different points and that there is exactly one line through a point that is parallel to a given line. Now these two properties can be taken as axioms and a new class of planes, called axiomatic affine planes, can be constructed. In particular, it is perfectly possible to construct such planes that have only a finite number of points and lines. Probably the most important conjecture in this area is the question what the possibilities are for the number of points in an axiomatic plane.

This project can take multiple directions, according to your interests. Examples are below, but you are certainly not limited to them:

If you are interested in a more algebraic approach, you can investigate the algebraic structures that can be used to coordinatise these axiomatic planes (just as we used the real numbers for our familiar plane). If you are interested in the more combinatorial side, you can look at known constructions of planes, look at the importance of Desargues' and Pappus theorem, investigate what kind of objects are the finite counterpart of conic sections, ... Finally, if you are interested in a link coding theory, you can investigate how coding theory was used to show that there is no finite plane of order 10.

Computing the Infinite
Hannes Diener

Since most mathematical objects are ideal/infinite, but computers can only ever deal with discrete/finite objects, it seems that we almost always have to confine ourselves to using approximations and shadow types (such as 'float' instead of the reals, or 'int' instead of the natural numbers) when transferring mathematical ideas to a computer.

Surprisingly though, it is possible to compute with (a large class of) infinite subsets of natural numbers, real numbers, and so on, not just as approximations, but as the actual objects.

In this project a student should investigate some of the mathematical background of such an approach, and ideally implement some of the ideas. Depending on the student's background the project can either focus on the theoretical mathematical foundations, or on the practical implementation. For the first a background in logic is welcomed (for example MATH130, 230, or

336), for the second some familiarity with a programming language which allows elements of 'functional programming' (such as `Python`, `Haskell`, `C++`) is useful.

Efficient use of ecosystems
Mike Plank

Ecosystems are complex networks of interactions among species. Many ecosystems are exploited by humans for food or other resources. Management objectives might include the maximising the resources harvested, maximising profit, or minimising disruption of the natural ecosystem. Modelling the ecosystem as a dynamical system and the harvesters as individual agents, this project will investigate how efficiently different strategies utilise the natural productivity of the ecosystem. This will initially be based on interaction data for the real ecosystem in Tuesday Lake, but the results have more general implications for how we manage exploited ecosystems, such as fisheries.

The project will involve a mixture of analytical techniques from dynamical systems and computer simulations. Some experience with Matlab or other programming language would be beneficial. It is not necessary to have taken any biology courses, though an interest in biology is essential.

Phylogenetic Networks
Charles Semple

Phylogenetic networks generalise phylogenetic (evolutionary) trees by allowing for non-treelike evolutionary events such as hybridisation and lateral gene transfer. The mathematical study of phylogenetic networks is recent and, arguably, no more more that fifteen years old. From a mathematical viewpoint, phylogenetic networks are simply rooted acyclic directed graphs. Many questions concern the structural properties of phylogenetic networks such as how hard is it to decide if a given tree is embeddable in a given network, and when is a network determined by its path-length distances? In this project, we investigate these and other related questions. The project involves discrete mathematics but there are no formal prerequisites.

Galois Theory and Geometry
Brendan Creutz

Galois theory provides a beautiful connection between field theory, group theory and geometry. This project will explore this theme in detail. There are a number of specific projects in this area ranging from computational to more theoretically oriented. Interested students should discuss with the supervisor. This project is suitable for students taking MATH411 Topics in Algebra.

Lax Pairs
Mark Hickman

Given a non-linear differential equation, a Lax pair is a pair of linear differential operators $\mathcal{L}$, $\mathcal{M}$ whose commutator vanishes only on solutions of the differential equation. A Lax pair allows one to potentially solve the differential equation by reducing the problem to an eigenvalue problem (if the operator $\mathcal{L}$ is second order, this is a Sturm-Liouville problem) and a time evolution of the eigenfunction; the so-called inverse scattering method. If $\mathcal{L}$ is first order then the Lax pair gives a conservation law of the differential equation. In this project, we will be looking at a method to compute the Lax pair of prescribed order for a differential equation (if it exists). This will involve Maple and would suit a student who has completed MATH302.

Topology (via Uniform Spaces)

Hannes Diener

A topological space is the most general notion of a space in mathematics. Even though topological spaces are governed by only three axioms many ideas of analysis, such as continuity and compactness, can be easily formulated in topology. In fact, many complicated and intricate ε-δ proofs actually become simpler once formulated in the language of topology.

In this project you will familiarise yourself with the basic ideas of a topology and then study uniform spaces, which are slightly less general than topological spaces, but allow one to talk about notions like uniform continuity and uniform convergence.

A background in either MATH336 or MATH343 would be helpful, but is not required.

Geometric codes

Gunter Steinke

Many important codes are derived from designs or objects in finite geometry. Typically the incidence matrix of such structures can be taken as the generator matrix of the code. Conversely, the investigation of associated codes can reveal interesting properties of related designs. For example, codes played a crucial part in the proof of the non-existence of finite projective planes of order 10.

The project looks at some of the connections between codes and designs/geometries. We may look at weight enumerators and how geometric properties are reflected therein.

Why has n-space $\mathbb{R}^n$ dimension n?

Gunter Steinke

While one has a precise notion of dimension for vector spaces, there often is an intuitive understanding of the dimension of a space (not necessarily a vector space) as the number of coordinates or parameters used to describe the space. However, this notion proved to be imprecise as discoveries in the early 20th century showed. There exist bijections between a line and a plane and also continuous maps from the unit interval onto the unit square. This led to the question of whether or not m-space and n-space can be *topologically* the same for different m and n. To answer this question various topological invariants have been devised.

Obviously, any useful invariant should assign n-space dimension n. While it is often easy to verify that n-space has dimension at most n, it is harder to establish equality.

The project investigates some possible definitions of the dimension of a (metric) space, their properties, when these dimensions agree and what examples of topological spaces there are for which they are different.

Projects in Statistics

Environmental Statistics

Jennifer Brown

Environmental monitoring is a fast moving, and important field of research. Data on environmental processes such as changes in water quality, endangered species distribution, weed invasion, and biodiversity are used to inform and guide how we manage our environment.

One use of environmental data is to build models to predict species distribution, and to predict the effect of environmental changes. In this project we will look at different methods used to collect field data and the effect of these differences on prediction models. We will use computer simulations to model data collection and analysis.

Statistical Sampling
Blair Robertson

A spatially-balanced sampling design selects sample locations that are well-spread over a study area, a sample with few 'clumps' or 'voids'. These designs are particularly useful when sampling natural resources because nearby locations interact with one another and are influenced by the same factors. In this project, the student will apply various spatially-balanced designs on simulated populations to investigate measures of spatial balance and variance estimation techniques.

Other Project Opportunities

Industry or Other Research Projects
Jennifer Brown

In addition, opportunities to work with industry partners or researchers at UC arise from time to time. These provide an excellent opportunity to work on problems of direct interest to industry or academic researchers, to learn more about working in an organisation outside of UC or as part of a research team at UC (or mixture of the two!).

These opportunities will usually be advertised on the School's website.

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