5000 level MT modules

- MT5095 Dissertation for MSc Mathematical Biology

  Semester
  Full Year
  Year
  2021/2
  Credits
  60.0

  This module is an individual dissertation where Mathematical Biology students are supervised by a member of the teaching staff who will advise on the choice of subject and provide guidance throughout the progress of the dissertation. The submission consists of a written report (not exceeding 15,000 words) alongside an oral presentation.

  Timetable
  To be arranged
  Lecturer
  Team Taught
  Prerequisites
  Antirequisites

  Lectures and tutorials
  Project meetings with supervisor, by arrangement

Assessment
Written report = 80%, Oral Presentation = 20%

Module coordinator
Dr N Sfakianakis

- MT5097 Portfolio Dissertation for Statistical Ecology MSc Programme

  Semester
  Full Year
Students will submit a portfolio comprising a range of outputs based on a single research topic. The submission will consist of a compulsory element (50% of the module grade) alongside a free choice element (50% of the module grade). The compulsory component comprises a report (maximum 4000 words, 30% of the module grade) alongside a reflective element (maximum 1000 words, 10% of the module grade), and an oral presentation (maximum 15 minutes, 10% of the module grade) summarising the project topic. For the free choice elements students can optionally choose either a 15-30 minute short film (modern essay, 50% of the module grade) or two of the following elements (25% each): podcast, webpage, poster, field report, training materials. The reflective element contained in the compulsory component describes (in part) why each portfolio element was chosen and describes the audience each element is intended to reach.

Timetable

Individual supervision by arrangement with supervisor

Lecturer

Team Taught

Prerequisites

Antirequisites

Lectures and tutorials

Project meetings with supervisor, by arrangement

Assessment

Coursework = 100%

Module coordinator

Dr C S Sutherland

Additional background to module

The module is intended for MSc students who want to get training and experience in using what might be called "non-traditional" media for communicating scientific research, as part of the research component of their MSc.

Intended Learning Outcomes

By the end of this module students will be able to
- Understand how to conduct research on a topic of the student's choice
- Be equipped with transferable skills in the communication of scientific work to lay and expert audiences
- Demonstrate ability to communicate scientific research effectively through oral presentations
- Demonstrate ability to communicate scientific research effectively through a written report
- Have experience of communicating scientific research through media other than oral presentation or written report, including some of the following: video, podcast, web page, poster, field report and training materials

**MT5098 Group Dissertation for MSc Programme/s**

Semester
- Full Year

Year
- 2021/2

Credits
- 60.0

This module is a group-based dissertation which is supervised by members of the teaching staff who will advise on the choice of subject and provide guidance and structure throughout the progress of the dissertation. This module results in an individually written and submitted dissertation of not more than 15,000 words. This dissertation may also include an agreed collaboratively written group report, but this report will constitute no more than 30% of the module grade. Each student is assessed taking into account both individual and group submissions.

Timetable
- To be arranged.

Lecturer
- Team Taught

Prerequisites
- Students must be enrolled on the MSc programme in the Applied Statistics and Data Mining.

Antirequisites
- You cannot take this module if you take MT5099

Lectures and tutorials
- 1-hour supervision (x 13 weeks)

Assessment
- Dissertation = 100%
Module coordinator
Dr V M Popov

Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate a knowledge and understanding of an advanced area of applied statistics and data mining
- Construct and evaluate logical arguments in the area of advanced study
- Present information and research in the area of advanced study in an appropriate manner
- Demonstrate skills in undertaking research as part of a team.
- Demonstrate competence in independent learning and time management

- [MT5099 Dissertation for MSc Programme/s]

Semester
Full Year
Year
2021/2
 Credits
60.0

Student dissertations will be supervised by members of the teaching staff who will advise on the choice of subject and provide guidance throughout the progress of the dissertation. The completed dissertation must be no more than 15,000 words.

Timetable
At times to be arranged with the supervisor.

Lecturer
Team Taught

Prerequisites

Antirequisites

Lectures and tutorials
Individual supervision

Assessment
Dissertation = 100%

Module coordinator
Prof J D Mitchell
Additional background to module

The dissertation module is only taken by postgraduate MSc students. It is completed during the summer months (from June to mid-August) under the supervision of a member of academic staff. The dissertation is worth 60 credits, which is a third of the number of credits required to complete your MSc. There are many forms for an MSc dissertation, the details of your particular project will be determined through discussions with your supervisor. Some possibilities include:

- A detailed account of a specific topic, perhaps building up to a significant highlight. This could be a topic outside those met in the taught part of your programme, and your undergraduate degree, or could take a topic that you have already encountered further.
- A survey style dissertation which discusses and compares a range of major ideas, with details presented briefly or intuitively.
- A mathematical or statistical investigation of a physical, biological or economic topic, or of a mathematical game, etc, perhaps using numerical, symbolic or statistical computation.
- A historical account, for example, the work of a mathematician or development of a topic, which would include both mathematical and historical analysis.

Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate a knowledge and understanding of an advanced area of mathematics/statistics
- Construct and evaluate logical arguments in the area of advanced study
- Present mathematics/statistics in the area of advanced study in an appropriate manner
- Demonstrate competence in independent learning and time management

- [MT5590 Independent Study Module](#)

Semester

Semester 2

Year

2021/2

Credits

15.0

This module provides the opportunity for a student to study an Advanced topic as a reading course under the supervision of a member of staff. The topic will be disjoint
from that of other taught modules, broadening the selection of advanced material available. Students will meet regularly with their supervisor and follow a planned programme of independent study, with associated assessment, as specified in the Letter of Agreement.

Timetable
- Weekly supervision as arranged with supervisor.

Lecturer
- Dr Antonia Wilmot-Smith

Prerequisites
- The student requires a letter of agreement

Antirequisites
- You cannot take this module if you take MT5990

Lectures and tutorials
- Typically 1 hour supervision each week.

Assessment
- Coursework = 100%

Module coordinator
- Dr A L Wilmot-Smith

This module runs in each semester every year.

Before enrolling on this module you must complete a Letter of Agreement (MT5590 Letter of Agreement (PDF), MT5590 Letter of Agreement (Word)).

Additional background to module

The Independent Study Module is a specialised module for students who are excelling in study at an advanced level (typically final year MMath/MPhys students or MSc students) and where alternative modules in the School are less appropriate as part of the overall balance in their degree programme. It may be suitable if you are particularly interested in an area of mathematics/statistics that is not part of our main module offering but essential for future studies (e.g. an MSc or PhD), or there is a good reason why you have not been able to take a taught module in the area.

It is the responsibility of each individual student to arrange a supervisor in the module. A first step is to speak with staff who work in the relevant area and seeing if any have availability, before (should discussions evolve positively) narrowing things down further via the Letter of Agreement. Advisers of Study or the Director of Teaching (for undergraduate students)/Director of Postgraduate Studies (for postgraduate students) can provide general advice about which staff have relevant expertise in a particular subject area.
Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate a knowledge and understanding of an advanced area of mathematics/statistics
- Construct and evaluate logical arguments in the areas of advanced study
- Present mathematics/statistics in the area of advanced study in an appropriate manner
- Demonstrate competence in independent learning and time management

MT5590 Independent Study Module

Semester
    Semester 1
Year
    2021/2
Credits
    15.0

This module provides the opportunity for a student to study an Advanced topic as a reading course under the supervision of a member of staff. The topic will be disjoint from that of other taught modules, broadening the selection of advanced material available. Students will meet regularly with their supervisor and follow a planned programme of independent study, with associated assessment, as specified in the Letter of Agreement.

Timetable
    Weekly supervision as arranged with supervisor.
Lecturer
    Dr Antonia Wilmot-Smith
Prerequisites
    The student requires a letter of agreement
Antirequisites
    You cannot take this module if you take MT5990
Lectures and tutorials
    Typically 1 hour supervision each week.
Assessment
    Coursework = 100%
Module coordinator
    Dr A L Wilmot-Smith
This module runs in each semester every year.

Before enrolling on this module you must complete a Letter of Agreement (MT5590 Letter of Agreement (PDF), MT5590 Letter of Agreement (Word)).

Additional background to module

The Independent Study Module is a specialised module for students who are excelling in study at an advanced level (typically final year MMath/MPhys students or MSc students) and where alternative modules in the School are less appropriate as part of the overall balance in their degree programme. It may be suitable if you are particularly interested in an area of mathematics/statistics that is not part of our main module offering but essential for future studies (e.g. an MSc or PhD), or there is a good reason why you have not been able to take a taught module in the area.

It is the responsibility of each individual student to arrange a supervisor in the module. A first step is to speak with staff who work in the relevant area and seeing if any have availability, before (should discussions evolve positively) narrowing things down further via the Letter of Agreement. Advisers of Study or the Director of Teaching (for undergraduate students)/Director of Postgraduate Studies (for postgraduate students) can provide general advice about which staff have relevant expertise in a particular subject area.

Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate a knowledge and understanding of an advanced area of mathematics/statistics
- Construct and evaluate logical arguments in the areas of advanced study
- Present mathematics/statistics in the area of advanced study in an appropriate manner
- Demonstrate competence in independent learning and time management

MT5599 Advanced Project in Mathematics / Statistics

Semester
- Full Year

Year
- 2021/2

Credits
- 30.0
This is a substantial project for final year students on integrated Masters degrees. The project will be chosen from a list published annually in the project booklet. It is also possible for students to nominate their own project, by agreement with a supervisor. Students will be required to investigate a topic in some depth, reporting regularly to their supervisor, submit a report by the end of April and give a presentation.

Timetable
   Regular supervision as arranged with supervisor.

Lecturer
   Team Taught

Prerequisites
   Available only to students in the final year of a MMath/MPhys honours degree programme in the School.

Antirequisites

Lectures and tutorials
   Typically and on average, 40 mins of project supervisions per week over whole year

Assessment
   Coursework = 100% (Project = 80%, Presentation = 20%)

Module coordinator
   Prof N Ruskuc

This module runs every year.

2021-2022

MMath honours projects 2021 - 2022 (PDF)

Online project choice form

2020-2021

MMath Honours Projects 2020 - 2021 (PDF)

Project Allocation Form 2020 - 2021 (PDF)

Additional background to module

In this module students undertake independent work, supervised by an expert member of staff, in a specific, advanced area of mathematics or statistics. The work may contain elements of original research, but this is not mandatory. The main final
outcome is a substantial written project, systematically presenting the area and student’s findings. Students are also asked to present their key findings in a short talk.

Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate understanding of the key mathematical or statistical concepts and methods in their chosen area for the project. This will contain some advanced material, either in the form of original work or understanding the current state of research on the subject
- Demonstrate an in-depth understanding of the significance of their subject matter and its links with other areas
- Have a good overview of the relevant literature and use it effectively in their investigations and writing
- Engage in independent and critical thinking within the area of the project
- Present their findings coherently in the written form
- Present their key findings in the form of a short oral presentation

**MT5731 Advanced Bayesian Inference**

**Semester**
Semester 1

**Year**
2021/2

**Credits**
15.0

This module examines the Bayesian framework for analysing statistical problems, including an introduction to the latest theoretical and practical developments in the field. The syllabus includes Bayes’ theorem, standard inference for conjugate Bayesian analyses, prediction, model comparison, principles of Bayesian computational techniques and software, and Markov chain Monte Carlo theory and applications. Instruction of advanced aspects of the Bayesian framework theory and its application is carried out by guided independent study, involving completion of a substantial project.

**Timetable**
Lectures: co-taught with MT4531. Monday (even) 10-11, Tuesday 10-11, Thursday 10-11; Practicals: co-taught with MT4531, Monday 1-2pm

**Lecturer**
Dr Nicolò Margaritella
Prerequisites
Before taking this module you must pass MT3507 or pass MT3508

Antirequisites
You cannot take this module if you take MT4531 or take MT5831

Lectures and tutorials
2.5 hours of lectures (10 weeks), 1-hour tutorial (9 weeks);

Assessment
2-hour written examination = 60%, Coursework = 40%.

Module coordinator

This module runs every year.

Additional background to module

The Bayesian approach is a complete theory in statistics, different in many ways from the standard approach encountered in previous modules. Just like the standard approach, we can use Bayesian statistics to design experiments, construct statistical models, estimate parameters, test hypotheses, make predictions, and provide interpretations of our outcomes. The module is concerned with both theory and applications. The syllabus includes Bayes' theorem, inference for samples from various distributions; linear and generalised linear modelling; elicitation of expert beliefs; choice of hypothesis and model comparison; principles of Bayesian computational, including Markov chain Monte Carlo. A substantial project on an advanced topic of Bayesian inference is an integral part of the module's assessment.

Intended Learning Outcomes

By the end of this module students will be able to

- Explain the principles that underline the Bayesian statistical paradigm
- Use the rules of probability to update beliefs for statistical model parameters given a set of observations, explain the main principles that underline the elicitation of expert beliefs, and use the rules of Bayesian statistics to predict future events
- Explain the main computational algorithms for implementing Bayesian statistical inference and use the Bayesian statistical software OpenBugs
- Select a hypothesis and perform model comparison
- Gain in-depth knowledge of an advanced topic of Bayesian inference

Reading List
MT5751 Estimating Animal Abundance and Biodiversity

Semester  
   Semester 2
Year  
   2021/2
Credits  
   15.0

The module will introduce students to the main types of survey method for wildlife populations. It will cover simple methods in some detail and provide students with a conceptual framework for building understanding of more advanced methods. In the case of multi-species surveys, it will also show how abundance estimates may be combined into biodiversity measures. By the end of the course, students will be able to identify an appropriate assessment method for a given population, design a simple survey to assess the population, perform simple analyses of survey data, and estimate biodiversity trends in a community. Students will get experience in using the methods via computer practical sessions involving design and analyses of surveys.

Timetable  
   12.00 noon Mon (odd), Wed and Fri
Lecturer  
   Dr Christopher Sutherland and Dr David Borchers
Prerequisites  
   Before taking this module you must pass MT3507 or pass MT3508 or pass MT5761
Antirequisites

Lectures and tutorials  
   2.5 lectures (x10 weeks), 1 computer practical or tutorial (x10 weeks)
Assessment  
   Coursework = 100%
Module coordinator  
   Dr C S Sutherland

From 2020/21 MT5751 will run in each year.

Additional background to module
This module is designed to equip students with the statistical and software tools for drawing inferences from wildlife survey data. The module would suit students interested in using these methods in conservation or wildlife management, and it also provides a basis for further academic study for someone interested in researching statistical methods for wildlife assessment.

Intended Learning Outcomes

By the end of this module students will be able to

- Understand the statistical foundations of the main types of wildlife survey methods, and the relationships between them
- Ability to identify an appropriate survey method for a given wildlife population and design a survey to apply the method to the population
- Ability to use wildlife survey data to draw statistically sound inferences about population abundance, distribution and trends, and the uncertainty associated with these inferences
- Ability to combine estimates from mult-species surveys into measures of biodiversity and biodiversity trend in a wildlife community
- Ability to use R software to estimate abundance, distribution and biodiversity from survey data

Print text supplementary reading material


MT5758 Multivariate Analysis

Semester
- Semester 2

Year
- 2021/2

Credits
- 15.0

This module provides theory and application for the analysis of multivariate data. Fundamental matrix material is presented including mean vectors, covariance matrices, correlation matrices and basic properties of multivariate normal distributions. Multivariate extensions to common univariate tests are subsequently
covered. Distance metrics and general measures of similarity are explored, leading to
the broader utility of multivariate methods in real-world problems, particularly for
classification and dimension reduction. The most common and fundamental methods
are covered, including Principal Components Analysis, multidimensional scaling,
clustering and discriminant analyses. The practical component of the module focuses
on analysis of real data using widespread software.

Timetable
   11.00 am Mon (even weeks), Tue and Thu

Lecturer
   Dr Theo Michelot

Prerequisites
   Before taking this module you must pass MT3507 or pass MT3508

Antirequisites
   You cannot take this module if you take MT4609

Lectures and tutorials
   2.5 lectures (x 10 weeks), and 4 tutorials and 4 project group meetings over the
   semester.

Assessment
   2-hour Written Examination = 50%, Coursework = 50%

Module coordinator
   Dr Theo Michelot

Pre-requisites for this module are under review. For 2019/20 the School of
Mathematics and Statistics will permit BSc and MA students to take this module
provided they have passed MT3507 or MT3508 and have permission from their
Advisor of Studies.

Additional background to module

Researchers and practitioners from various fields (bioinformatics, image processing,
finance etc.) are facing data sets with a large number of variables. Reducing the
dimensionality of the data becomes a key problem, for which multivariate methods
have been developed. In this module we provide a hands-on introduction to different
multivariate techniques, laying the emphasis on understanding of the methodology,
its application and the interpretation of the results, while providing the necessary
theoretical foundations.

We start by revising relevant concepts of matrix algebra and putting them in the
perspective of multivariate analysis. The core of the module is based on dimension
reduction techniques such as Principal Component analysis and Multi-dimensional
scaling. Furthermore, we discuss different approaches for grouping data (cluster
analysis). Finally we introduce an extension of linear regression for a multivariate response.

Intended Learning Outcomes

By the end of this module students will be able to

- Gain an intuitive understanding of central concepts and operations in matrix algebra such as matrix multiplication, eigenvectors and eigenvalues
- Learn techniques for exploratory data analysis, in particular for data visualisation
- Understand and apply Principal Component Analysis
- Learn techniques for dimension reduction based on distances between points (Multi-dimensional scaling)
- Understand and apply methods for grouping observations (Cluster Analysis)
- Understand and apply techniques for reducing the number of relationships between variables (Multivariate Regression)

- **MT5761 Applied Statistical Modelling using GLMs**

  Semester
  Semester 1

  Year
  2021/2

  Credits
  15.0

  This applied statistics module covers the main aspects of linear models (LMs) and generalized linear models (GLMs). In each case the course describes model specification, various options for model selection, model assessment and tools for diagnosing model faults. Common modelling issues such as collinearity and residual correlation are also addressed, and as a consequence of the latter the Generalized Least squares (GLS) method is described. The GLM component has emphasis on models for count data and presence/absence data while GLMs for multinomial (sometimes called choice-based models) are also covered for nominal and ordinal response outcomes. The largest part of the course material is taught inside an environmental impact assessment case study with reality-based research objectives. Political and medical examples are used to illustrate the multinomial models.

  **Timetable**
  
  Mon, Tues, Thur, Fri 3:00 - 4:00 (lectures), Tues, Thur 4:00 - 5:00 (practicals)

  **Lecturer**
Prerequisites
Undergraduates must have passed at least one of MT4113, MT4527, MT4528, MT4530, MT4531, MT4537, MT4539, MT4606, MT4608, MT4609, MT4614.

Antirequisites
You cannot take this module if you take MT4607 or take MT5753

Lectures and tutorials
4 lectures (x 5 weeks), 2 practicals (x 5 weeks)

Assessment
2-hour Written Examination = 50%, Coursework = 50%

Module coordinator
Dr V M Popov

Additional background to module

This module extends ordinary regression models and covers methods that are an essential part of any applied statistician’s toolbox. It has a very applied focus and will be of interest to someone wanting to use statistical methods to solve real-world problems, and not of so much interest to someone wanting to understand the theoretical foundations or mathematical proofs underlying the methods.

Intended Learning Outcomes

By the end of this module students will be able to

- Understand Generalised Least Squares (GLS) models and how they relate to Linear regression Models (LMs), and be able to apply GLS models appropriately
- Understand how Generalised Linear Models (GLMs) extend LMs and GLS models, recognise problems whose solution requires GLMs, and be able to apply GLMs appropriately to address such problems
- Learn to apply GLMs for continuous response data, count data, binary data, ordinal data and categorical data
- Be able to perform objective model selection and conduct diagnostics for GLS models and GLMs, to check models’ adequacy for the data at hand
- Be able to interpret fitted GLS model and GLMs output to draw appropriate conclusions about the problem being addressed using these models
- Become competent in using the statistical programming language R to solve problems using GLS models and GLMs

MT5762 Introductory Data Analysis

Semester
Semester 1

Year

2021/2

Credits

15.0

This module provides coverage of essential statistical concepts and analysis methods relevant to commercial analysis. Specifically: the different types of data and their numerical/graphical treatment; basic probability theory and concepts of inference; fundamental statistical concepts with particular emphasis on sampling issues; basic statistical models and tests; linear models; introductory computer-intensive inference. This module is a short intensive course and is a core, preliminary, requirement for the MSc in Applied Statistics and Datamining. It covers material essential for study of the more advanced statistical methods encountered in subsequent modules.

Timetable

Monday, Thursday, Friday 3:30pm-5pm and Tuesday 4pm-5:30pm

Lecturer

Dr David Borchers

Prerequisites

Students must have gained admission onto an MSc programme

Antirequisites

You cannot take this module if you take MT5756

Lectures and tutorials

Four 1.5-hour lectures (x 5 weeks), 1 tutorial (x 5 weeks)

Assessment

Coursework = 100%

Module coordinator

Prof D L Borchers

This module is not available to Undergraduate students.

Additional background to module

A preliminary statistics module largely intended for MSc students on Applied Statistics and Datamining, Data-Intensive Analysis and relevant programmes within the Graduate school. The module moves rapidly through basic statistics to linear models, covering general theory with a strong emphasis on application. Topics between these points include sampling, experimental design, variable/data types and their numerical and graphical summaries, basic probability, probability distributions, inference (including sampling distributions, CLT, tests and confidence intervals), basic tests and models with emphasis from a linear model perspective, multiple
comparisons and power. R is used as the exemplar language throughout and entirely internally assessed – predominantly projects with a class test.

Intended Learning Outcomes

By the end of this module students will be able to

- Understanding of fundamental applied statistical tests and models, ranging from simple univariate tests to linear models
- Understanding of the basics of survey and experimental design and associated sampling strategies and biases
- The fitting and interpretation of simple models with R as the exemplar language
- Summarising and presentation of data, along with reporting of the results of statistical models to lay and technical audiences

MT5763 Software for Data Analysis

Semester
   Semester 1
Year
   2021/2
Credits
   15.0

This module covers the practical computing aspects of statistical data analysis, focussing on packages most widely used in the commercial sector (R, SAS, SPSS and Excel). We cover the accessing, manipulation, checking and presentation of data (visual and numerical). We fit various statistical models to data, with subsequent assessment, interpretation and presentation. Good practice and ‘reproducible research’ is covered, as is computer intensive inference and big data considerations. This module is a short intensive course and is a core, preliminary, requirement for the MSc in Applied Statistics and Datamining and the MSc in Data Intensive Analysis. It covers material essential for study of the more advanced statistical methods encountered in subsequent modules.

Timetable
   Tuesday, Wednesday, Thursday, Friday 2-3:30pm.
Lecturer
   Dr Carl Donovan and Dr Charles Paxton

Prerequisites
Before taking this module you must pass MT1007 or pass MT3507 or pass MT3508 or take MT5762

Antirequisites

You cannot take this module if you take MT5756

Lectures and tutorials

Three 2-hour lecture/practical classes (x 5 weeks)

Assessment

Coursework = 100%

Module coordinator

Dr C R Donovan

Additional background to module

An R & SAS software module largely intended for MSc students on Applied Statistics and Datamining, Data-Intensive Analysis and relevant programmes within the Graduate school. The module covers practical computing for the analysis of data. This includes the manipulation and presentation of data (data munging/wrangling/summarising in dplyr, plotting in ggplot); accessing data via web-scraping and APIs; reproducible research using (R-)markdown and version control in Github; interactive web-applications using Shiny; code profiling and optimisation; fitting of linear models in SAS and R and presentation of results; computer-intensive inference in SAS & R (randomisation test and bootstrapping); parallelisation. Entirely internally assessed by means of various project work, including a group project ending in a version-controlled interactive web application.

Intended Learning Outcomes

By the end of this module students will be able to

- The basics of programming and model fitting in SAS and R, along with computer intensive inference
- Familiarisation with principles and practice of reproducible and collaborative research, built around the concepts of mark-down analysis documents, version control and github repositories
- The practical presentation of data and models to lay and technical audiences in a variety of forms
- The development of basic interactive applications to provide GUls for model fitting and data analysis
- Accessing and manipulating data from APIs or web-scraping

Reading List

- Grolemund & Wickham, *R for Data Science*. 
This module covers modern modelling methods for situations where the data fails to meet the assumptions of common statistical models and simple remedies do not suffice. This represents a lot of real-world data. Methods covered include: nonlinear models; basic splines and Generalised Additive Models; LASSO and the Elastic Net; models for non-independent errors and random effects. Pragmatic data imputation is covered with associated issues. Computer intensive inference is considered throughout. Practical applications build sought-after skills in R and the commercial packages SAS.

Timetable

Mon 12:00-1:00 Weeks 2, 4, 6, 8, 10
Tues; Thur 12:00-1:00, Weeks 1-10
(lectures); Mon 2:00 - 4:00 Weeks 2-9 (practicals)

Lecturer
Dr Rachel Sippy

Prerequisites
Before taking this module you must pass MT3508 and ( pass MT4606 or pass MT5761 )

Antirequisites
You cannot take this module if you take MT5757

Assessment
2-hour Written Examination = 60%, Coursework = 40%

Module coordinator
Dr Rachel Sippy

Additional background to module

This module covers modern statistical modelling methods for situations where the data fail to meet the assumptions of Gaussian linear models, and simple remedies (such as data transformation) do not suffice. This represents a lot of real-world data. Methods covered include penalized regression, nonlinear modelling using smoothers, models for correlated errors and random effects. The emphasis throughout is on
practical application of the methods to real-world datasets – on understanding and testing the assumptions and deciding which methods to use when. Hands-on skills are taught using the computer software R and SAS.

Intended Learning Outcomes

By the end of this module students will be able to

- Show how generalized linear models can be extended to accommodate correlated errors and nonlinear systematic relationships
- Understand modern statistical modelling methods including LASSO, elastic net, generalized additive models, generalized estimating equations and random effects
- Apply them to real-world data using R and SAS
- Validate model assumptions and select between models

MT5765 Medical Statistics

Semester
- Semester 2
Year
- 2021/2
Credits
- 15.0

This module will cover a number of topics in medical statistics, that are important areas both in terms of methodological development and application. The main topic covered will be Survival Analysis, with others selected from Meta-analysis, Power calculations, Prospective vs Observational studies, Sequential analyses, Clinical trials.

Timetable
- 10:00 - Mon (odd weeks), Wed, Fri
Lecturer
- Dr Andy Lynch
Prerequisites
- Before taking this module you must pass MT3507 or pass MT3508
Antirequisites

Lectures and tutorials
- 2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)
Assessment
- Coursework = 35%, 2-hour Written Examination = 65%
Module coordinator
Prof A G Lynch

This module is not running in 2022-2023. It is expected to run in 2023-24 and then in every year thereafter.

Additional background to module

Biomedical research and practice employs many mathematical and statistical graduates. While there are few if any areas of statistics that are exclusively used by medical statisticians, there are some that are essential for this role. With a focus on practical application, MT5765 Medical Statistics covers a range of topics (e.g. Survival analysis, trial design and meta-analysis) that should better prepare graduates for a career in the biomedical sciences. As such the module might complement others such as Design of Experiments, Population Genetics, Mathematical Oncology and Mathematical Biology. Although we take a medical focus within the module, the methods covered will be widely applicable in other fields.

Intended Learning Outcomes

By the end of this module students will be able to

- Appreciate a range of challenges when applying statistical methods in medical settings
- Understand a range of approaches to analysing ‘time-to-event’ data with censored observations (survival analysis) and will have applied them to real data
- Understand a range of approaches for combining the results of multiple studies (meta-analysis) and will have applied them to real data
- Criticise the presentation of results in medical journals and be aware of how to design, analyse, and present their own medical studies

MT5766 Statistical Problem Solving

Semester
Full Year

Year
2021/2

Credits
15.0
The module will focus on problem formulation and scientific reporting to different audiences. The module will consist of a set of case studies covering a range of application areas, for example, ecology, economics and medicine. The case studies will take the form of a key research question posed in a non-statistical way with an associated data set where appropriate. Students will be required to formulate the posed questions as a statistical problem and decide upon appropriate techniques to apply in each case. The coursework produced will be targeted at audiences ranging from readers of statistical journals to the general public. The form of the coursework will be different for each case study offering students the opportunity to improve their scientific writing and presentation skills. The module will also cover the importance of data protection and ethics approval alongside the promotion of science and statistics to wider audiences.

**Timetable**
- Lecture/Practical (Thursday 2pm)

**Lecturer**
- Dr Hannah Worthington

**Prerequisites**
- Before taking this module you must pass MT3507 or pass MT3508

**Antirequisites**
- You must also take MT4113

**Lectures and tutorials**
- 1 Lecture (x6 weeks), 1 practical (x16 weeks), 1 seminar (x2 weeks)

**Assessment**
- Coursework = 100%

**Module coordinator**
- Dr H Worthington

This module is not running in 2022-2023. It is expected to run in 2023-24 and then in every year thereafter.

**Additional background to module**

This module looks to introduce and explore the research process. Formed of several case studies, the module will develop the skills of taking a vague problem statement or data set and formulating an appropriate statistical problem putting into practice techniques and methods that have been met in other modules. The module also focusses on the communication of statistics to highly varied audiences, practising the use of appropriate language and conveying results in a clear and informative manner. Transferable skills will be gained through the format of the coursework which will include short presentations, podcasts/pencasts, press releases and written reports.
Intended Learning Outcomes

By the end of this module students will be able to

- Formulate an appropriate statistical problem from a research question or dataset
- Understand the different stages of the research process
- Communicate statistics to different audiences in different formats
- Understand and appreciate the importance of data protection and ethics
- Use R as a tool for analysis and the visualisation of data and results

MT5767 Modelling Wildlife Population Dynamics

Semester
Semester 1
Year
2021/2
Credits
15.0

This module will introduce students to methods for constructing mathematical models of wildlife population dynamics and of fitting these models to diverse data from wildlife surveys. It will begin with an introduction to the key demographic processes that govern population dynamics, and how these can be represented within discrete-time age- and stage-structured models. Types of relevant wildlife survey data will then be considered, before turning to the approaches for fitting these data to the population models. Both classical and Bayesian approaches will be considered. Practical experience will be gained through tutorials and through two assignments.

Timetable
10.00 am Mon (odd weeks), Wed, Fri
Lecturer
Dr Chris Sutherland
Prerequisites
Before taking this module you must pass MT3507 or pass MT3508
Antirequisites

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 practical (x 10 weeks)
Assessment
Coursework = 100%
Module coordinator
Dr C S Sutherland

Additional background to module

This module will introduce students to methods for constructing mathematical models of wildlife population dynamics and of fitting these models to diverse data from wildlife surveys. It will begin with an introduction to the key demographic processes that govern population dynamics, and how these can be represented within discrete-time age- and stage-structured models. Types of relevant wildlife survey data will then be considered, before turning to the approaches for fitting these data to the population models. Both classical and Bayesian approaches will be considered. Practical experience will be gained through hands-on exercises and assignments.

Intended Learning Outcomes

By the end of this module students will be able to

- Construct age- and stage-structured population models of wildlife populations
- Understand key demographic processes such as density dependence and how they affect population growth
- Describe the main sources of data used to inform population models
- Fit models to these data using both classical and Bayesian methods

Reading List


- **MT5842 Advanced Analytical Techniques**

Semester

- Semester 2

Year

- 2021/2

Credits

- 15.0

This module introduces students to important advanced applied analytic techniques such as Variational Calculus, Integral equations and transforms, solutions to differential equations by contour integrals, and the theory of Steepest Descent.
Timetable
12noon Monday (odd weeks), Wednesday, Friday

Lecturer
Prof Alan Hood

Prerequisites
Before taking this module you must pass MT3503

Antirequisites
You cannot take this module if you take MT5802

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment
2-hour written examination = 75%, coursework =25%

Module coordinator
Prof A W Hood

This module runs each year.

Intended Learning Outcomes

By the end of this module students will be able to

- Use the Neumann Series and Laplace transform method to solve Fredholm and Volterra integral equations
- Understand the use of variational calculus and derive the Euler-Lagrange equations to derive the extremum of an integral
- Determine a simple estimate of the lowest eigenvalues in Strum-Liouville problems
- Express the solution of certain ordinary differential equations in terms of a contour integral and determine the appropriate contour
- Use the method of Steepest Descents to derive estimates of contour integrals for a large parameter

Syllabus
- Fredholm Integral equations of first and second kind
- Volterra Integral equations of first and second kind
- Calculus of variations
- Eigenvalue problems
- Solutions of ODEs by contour integrals of Laplace linear equations
- Theory and Applications of Steepest Descent

- MT5846 Advanced Computational Techniques
This module introduces students to some of the ideas, techniques and constraints that underpin modern approaches to the numerical modelling of physical processes that may be described by partial differential equations. Students will gain experience in implementing a variety of standard numerical methods where they will carry out three projects involving code development, testing and analysis/interpretation of results.

Timetable
12 noon Monday (even weeks), Tuesday, Thursday.

Lecturer
Dr Alexander Stewart

Prerequisites
Before taking this module you must pass MT3802 and pass MT4112

Antirequisites
You cannot take this module if you take MT5806

Lectures and tutorials
2 lectures (x 10 weeks), 1 practical (x 11 weeks)

Assessment
Coursework = 100%

Module coordinator
Dr A J Stewart

This module runs each year.

Additional background to module

The aim of this module is to further build on the knowledge acquired in "Computing in Mathematics" (MT4112) and "Numerical Analysis" (MT3802). This involves numerically solving partial differential equations (PDEs) by coding various methods using Fortran. The analysis and visualisation of data generated from Fortran codes using an appropriate visualisation package will be studied.

Intended Learning Outcomes

By the end of this module students will be able to
Be familiar with standard numerical methods for solving partial differential equations
Have an understanding of how some basic PDEs can be applied to real world problems
Be confident in coding the introduced PDEs using various numerical methods
Demonstrate data visualisation skills using appropriate software
Be able to write/present scientific reports in a well structured and readable form

MT5849 Geophysical Fluid Dynamics

Semester
Semester 1
Year
2021/2
Credits
15.0

This module will examine current research in fluid dynamics, with a particular focus on meteorology and oceanography. The large-scale atmosphere and oceans behave quite unlike a ‘classical’ fluid owing to the presence of stable density stratification and rotation. As a result, the fluid motion is dominated by slow, ‘vortical’ or eddying motions (like cyclones) which generally spin slower than the Earth. Superimposed on this slow motion are relatively fast wave-like motions analogous to surface waves on a pond. These lectures describe the mathematical basis of these fundamentally different types of motion, and furthermore illustrate the increasingly important role of computer modelling in this research.

Timetable
11am Monday (odd weeks), Wednesday, Friday

Lecturer
Dr Richard Scott

Prerequisites
Before taking this module you must pass MT4509

Antirequisites
You cannot take this module if you take MT5809

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment
2-hour written examination = 100%

Module coordinator
Dr R K Scott

This module runs each year.

Additional background to module

The module studies the dynamics of rotating, stratified flows, applicable to the large scale motions of atmospheres and oceans. Starting from the equations of motion, it derives dispersion relations for a variety of linear wave solutions and uses these to interpret observed atmospheric/oceanic motions. Scale analysis provides approximations to the full equations when appropriate physical parameters can be assumed small.

Intended Learning Outcomes

By the end of this module students will be able to

- Understand the separate and combined effects of rotation and stratification on fluid motions
- Derive and interpret the dispersion relation for linear waves in rotating, stratified fluids
- Perform a scale analysis of the equations of motion and understand how it leads to the quasigeostrophic model under appropriate assumptions
- Understand the use and significance of potential corticity
- Understand the shallow water equations as a reduced model of geophysical flows

Syllabus

- Review of basic concepts
- Kelvin’s Circulation theorem and link with potential vorticity
- Rotating flows (including PV for a rotating fluid)
- Inertial waves (including dispersion relation and properties)
- Rotating fluids: Taylor-Proudman Theorem
- Stratified fluids (including the Boussinesq approximation)
- Stratified, rotating fluids (including properties of inertial-gravity waves)
- Quasi-Geostrophic model
- Shallow water equations

Reading List


Print text supplementary reading material

- **MT5850 Advanced Solar Theory**

  Semester
  Semester 1
  Year
  2021/2
  Credits
  15.0

  The object of this module is to describe the magnetohydrodynamic processes at work in the Sun, using modern techniques of applied mathematics, and to discuss the latest theories in relation to aspects of current research within the School.

  **Timetable**
  12 noon Monday (even weeks), Tuesday, Thursday

  **Lecturer**
  Prof Thomas Neukirch

  **Prerequisites**
  Before taking this module you must pass MT4510

  **Antirequisites**
  You cannot take this module if you take MT5810

  **Lectures and tutorials**
  2.5 lecture (x 10 weeks), 1 tutorial (x 10 weeks)

  **Assessment**
  2-hour written examination = 100%

  **Module coordinator**
  Prof T Neukirch

  This module runs each year.

  **Additional background to module**

  The Sun is our nearest star and displays a host of exciting phenomena that can not only be found in other stars, but also in more exotic astrophysical objects throughout the Universe. The subtle interaction between the ionised gas of which the Sun and its atmosphere consist (called a plasma) and the complex solar magnetic field is the key to our understanding of many of the processes we observe on the Sun. The mathematical theory underpinning this understanding is magnetohydrodynamics (MHD). In this module we will build on the knowledge and the skills acquired by the
students in MT4510 Solar Theory to gain a deeper understanding of the MHD equations themselves and to study the way in which different forms of energy are transported and converted within MHD. The module will also cover MHD equilibria, MHD waves, MHD instabilities, magnetic diffusion and reconnection and how these theoretical topics are linked to solar applications.

Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate an advanced understanding of magnetohydrodynamics (MHD), in particular with regards to solar applications
- Formulate and apply advanced MHD models to describe a large variety of solar phenomena
- Demonstrate that they have acquired the mathematical skills to carry out complex and advanced calculations using the MHD equations
- Analyse, interpret and evaluate sophisticated mathematical calculations in the context of solar applications
- Solve unseen advanced mathematical problems based on the MHD equations

Syllabus

- Overview of solar observations and phenomena
- The magnetohydrodynamic (MHD) equations and their properties
- Magnetic field structure (including magnetic null points)
- MHD equilibria
- MHD waves
- MHD instabilities
- Magnetic reconnection

Reading list

- Goedbloed, Keppens and Poedts, *Magnetohydrodynamics of Laboratory and Astrophysical Plasmas*, CUP 2019
- Boyd & Sanderson, *Physics of Plasmas*, CUP
- Schnack, *Lectures in MHD*, Springer

Print text supplementary reading material

This module will explore real world applications of mathematics to biological and medical problems (e.g. cell movement, pattern formation in animal coat markings, spread of infectious diseases). The mathematical models that will be considered are mostly formulated in terms of nonlinear partial differential equations whose solutions can exhibit a range of interesting behaviour. The module will be useful to students who wish to specialise in Applied Mathematics in their degree programme.

Timetable
- 9am, Monday (odd weeks), Wednesday, Friday

Lecturer
- Dr Alexander Stewart

Prerequisites
- Before taking this module you must pass MT3504

Antirequisites
- You cannot take this module if you take MT5852

Lectures and tutorials
- 2.5 lectures (x 10 weeks), 10 tutorials (x 10 weeks)

Assessment
- 50 minute class test = 10%, 2-hour written examination = 90%

Module coordinator
- Dr A J Stewart

This module runs each year.

Additional background to module

This module will explore real world applications of mathematics to biological and medical problems (e.g. cell movement, pattern formation in animal coat markings, spread of infectious diseases). The mathematical models that will be considered comprise mostly nonlinear partial differential equations whose solutions can exhibit a range of interesting behaviours.

Intended Learning Outcomes
By the end of this module students will be able to

- Define mathematical models for the spatio-temporal evolution of biological systems using partial differential equations
- Formally derive mathematical models formulated in terms of partial differential equations from underlying random walks
- Analysing travelling wave solutions of partial differential equations
- Use linear stability analysis to explore the conditions for the emergence of spatial patterns in systems of partial differential equations

Syllabus

- Conservation equations
- Linear and nonlinear reaction-diffusion equations
- Systems of nonlinear reaction-diffusion equations
- Models of chemotaxis
- Reaction-diffusion models of pattern formation
- Mechanoschemical models of pattern formation

Reading list


Print text supplementary reading material

Cancer is a complex disease, the second largest cause of death throughout the world (after cardiovascular diseases). Beginning with genetic mutations in a single cell, cancer progresses through several key growth phases - the avascular growth phase (nutrient delivered by diffusion of oxygen), tumour-induced angiogenesis (blood vessel growth), invasion and metastasis (spread to secondary parts of the body). Because of its complexity and multiscale nature (temporal and spatial), treatment of cancer is challenging. This module will introduce students to the mathematical modelling of the key phases of cancer growth and treatment via immunotherapy, chemotherapy and radiotherapy. The mathematical techniques used in the modelling will be nonlinear partial differential equations, and students will be exposed to current research taking place within the Mathematical Biology research group in the School of Mathematics and Statistics.

**Timetable**
- 9am, Monday (odd weeks), Wednesday, Friday

**Lecturer**
Dr Nikolaos Sfakianakis

**Prerequisites**
Before taking this module you must pass MT3504

**Antirequisites**

**Lectures and tutorials**
- 2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

**Assessment**
- 50 minute class test = 10%, 2-hour written examination = 90%

**Module coordinator**
Dr N Sfakianakis

This module runs each year.

**Additional background to module**

In this module we study several mathematical models that describe the growth and metastasis of cancer, as well as the biomedical processes that take place during immune response of the organism and the employment of tumour-specific therapies. These models take the form of combined systems of Ordinary-, Partial-, and Stochastic-Differential Equations. Our study includes the development of the corresponding models, components of their mathematical analysis, as well as numerical simulations and biologically relevant experiments. It is expected that at the end of this module we will be able to navigate safely through the relevant mathematical and biomedical literature with safety, and engage with currently open
research questions in the fields of academic as well as industrial Mathematical Oncology.

Intended Learning Outcomes

By the end of this module students will be able to

- Be trained in the biomedical terminology and the corresponding biological processes, through the study of the modern and historical literature in Mathematical Oncology
- Rigorously model the growth of cancer, angiogenesis, the invasion of the extracellular matrix, metastasis, and more biological processes in cancer through Ordinary-, Partial-, and Stochastic-Differential Equations
- Use linear stability analysis to identify conditions for the emergence of patterns in the interaction of cancer with the environment
- Develop algorithms and computer codes to simulate and study the dynamics of various cancer growth and invasion models

Syllabus

- Intracellular modelling - gene regulatory networks and transcription factors
- Nonlinear ODE and PDE models of avascular tumour growth
- Models of the immune-response to cancer
- Models of tumour-induced angiogenesis
- Modelling chemotherapy and radiotherapy treatment

Print text supplementary reading material

This module will provide an introduction to stochastic modelling with a focus on applications in biology. It will introduce and explain key biological phenomena where stochastic effects are important, such as stochastic amplification (the emergence of stochastically-enabled oscillations) and stochastic resonance and focussing, where stochastic dynamics can change systems behaviour due to non-linear interactions. The module will include Bayesian techniques that may be used to infer parameters of stochastic models. Stochastic methods are increasingly used in applied maths and in mathematical biology in particular, both in research and in industrial settings. This module aims to equip students with the skills to understand stochastic dynamical systems and complements other modules in the School where dynamical systems are widely discussed using deterministic descriptions such as ODEs or PDEs. Here students learn how to extend such systems to take stochastic effects into account.

Timetable
- 10am Monday (even weeks), Tuesday, Thursday
Lecturer
- Dr Jochen Kursawe
Prerequisites
- Before taking this module you must pass MT2508 and pass MT3504
Antirequisites

Lectures and tutorials
- 2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)
Assessment
- Coursework (computing project) = 20%, 2-hour Written Examination = 80%
Module coordinator
- Dr J Kursawe

- **MT5856 Calculus of Variations in Biological Modelling**

Semester
- Semester 1
Year
- 2021/2
Credits
- 15.0

This module introduces students to the mathematical modelling of biological processes using the Calculus of Variations as its main tool. It starts with an introduction to the Calculus of Variations and its historical applications and continues
to modern applications in Mathematical Biology. Students will gain first-hand experience in confronting research-level modelling questions as well as in applying advanced mathematical techniques in the biological setting.

Timetable
10am Monday (odd weeks), Wednesday, Friday

Lecturer
Dr Nikolaos Sfakianakis

Prerequisites
Before taking his module you must pass MT3504 and pass MT3802

Antirequisites

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment
Coursework (2 x 25% projects) = 50%, 2-hour Written Examination = 50%

Module coordinator
Dr N Sfakianakis

• MT5861 Advanced Combinatorics

Semester
Semester 2

Year
2021/2

Credits
15.0

Combinatorics underlies and interacts many topics in discrete mathematics including group theory, statistical design, and statistical mechanics, as well as being a lively subject in its own right. The module will give students a good grounding in the techniques and will engage students with research-level problems. It is designed to make a wide area of combinatorics available to students.

Timetable
12 noon Monday (odd weeks), Wednesday, Friday.

Lecturer
Prof Peter Cameron

Prerequisites
Before taking this module you must pass MT4514 or pass MT4516

Antirequisites
You cannot take this module if you take MT5821
Lectures and tutorials
2.5 lectures (x10 weeks), 1 tutorial (x10 weeks)

Assessment
2-hour written examination = 100%

Module coordinator
Prof P J Cameron

This module runs in alternate years.

Intended Learning Outcomes

By the end of this module students will be able to

Strand 1:
- Translate between recurrence relations for counting sequences and expressions for their generating functions
- Apply techniques of formal power series to obtain combinatorial information
- Use algebraic techniques (from linear algebra, polynomials or group theory) to obtain information about combinatorial structures or their enumeration
- Exhibit and use consequences of combinatorial techniques in other parts of mathematics such as counting finite fields and Möbius functions of groups

Strand 2:
- Calculate cycle index of permutation group and apply to counting up to symmetry
- Apply inclusion-exclusion to count restricted functions or colourings
- Use algebraic techniques (from linear algebra, polynomials or group theory) to obtain information about combinatorial structures or their enumeration
- Calculate the weight enumerator of a code as a specialisation of the Tutte polynomial of a matroid

Strand 3:
- Use linear algebraic techniques to restrict parameters of combinatorial objects such as graphs
- Translate between classification of root systems and classification of combinatorial and geometric objects
- Use algebraic techniques (from linear algebra, polynomials or group theory) to obtain information about combinatorial structures or their enumeration
- Find combinatorial properties of polar spaces over the 2-element field from their algebraic description
Syllabus

A selection from the following will be covered. It is envisaged that the module in a given year will cover one of the following areas:

1. Enumerative combinatorics: basic counting, formal power series and their calculus, recurrence relations, q-analognes, group action and cycle index, species, asymptotic results.
2. Graphs, codes and designs: strongly regular graphs, t-designs, optimality for block designs, codes and weight enumerators, matroids and Tutte polynomial, MacWilliams relations.
3. Projective and polar spaces: geometry of vector spaces, combinatorics of projective planes, sesquilinear and quadratic forms and their classification, diagram geometry, classical groups.

Print text supplementary reading material

Strand 1:
- Alan Slomson, Introduction to combinatorics, Chapman and Hall;
- Richard Stanley, Enumerative Combinatorics, CUP.

Strand 2:
- Cameron and van Lint, Graphs, Codes, Designs and their Links, CUP.

Strand 3:
- Artin, Geometric Algebra, Interscience;

MT5862 Discrete Geometry

Semester
- Semester 1
Year
- 2021/2
Credits
- 15.0

Discrete geometry is concerned with combinatorial properties of geometric objects such as point sets, arrangements of affine and projective subspaces, convex polytopes, and geometric graphs. This module introduces the area, covering the basic objects and selected key results.
Timetable
   Lectures - Monday (odd weeks), Wednesday, Friday - 12 noon

Lecturer
   Dr Louis Theran

Prerequisites
   Before taking this module you must pass MT2504 and pass MT3501 and ( pass MT3502 or pass MT3505 or pass MT3852 or pass MT4003 or pass MT4514 or pass MT4516 or pass MT4512 )

Antirequisites

Lectures and tutorials
   2.5 hour lectures (9 weeks), 1 hour tutorial (10 weeks)

Assessment
   2-hour Written Examination = 100%

Module coordinator
   Dr L S Theran

This module runs in alternate years.

Additional background to module

Discrete geometry is concerned with geometric objects that are constructed from affine points, lines, hyperplanes, etc and their combinatorial properties. This module starts by developing the necessary background in affine and convex geometry necessary to develop the theory of convex polytopes in general dimension. We then look at intersection patterns of convex sets, the combinatorics of hyperplane arrangements, and combinatorically interesting polytope families. The last section explores dimensions 2 and 3 in details, covering planar graphs, their representations and polytopes, and applications to incidence geometry / sum-product estimates.

Intended Learning Outcomes

By the end of this module students will be able to

- Know how to work with the basic objects of discrete geometry: point configurations, hyperplane arrangements, polytopes, and geometric graphs. This means being able to define them, state the important properties, and use them to construct proofs that solve unseen problems.
- Be able to define projective duality and translate problems about point configurations to ones about hyperplane arrangements and vice versa. In particular, students will know and use the building blocks of the proof of the Main Theorem of Polytopes and apply the theorem itself.
Know how to apply combinatorial methods to geometric problems and use geometric representations of combinatorial objects to go in the other direction. Examples include using Ramsey’s Theorem to find large cyclic subsets of point configurations and solving combinatorial partitioning problems using the Ham Sandwich Theorem.

Be able to state and prove Euler’s formula for planar graphs (assuming appropriate topological results) and be able to apply it to derive structural properties of planar graphs and results such as the Crossing Number Lemma.

Syllabus
- Introduction to discrete geometry
- Arrangements
- Polytopes
- Planar graphs
- Extremal questions

Print text supplementary reading material
- Lectures on discrete geometry, Jiří Matoušek (2002), Springer-Verlag New York
- Discrete and computational geometry, Satyan L. Devadoss & Joseph O’Rourke (2011), Princeton University Press

- **MT5863 Semigroups**

Semester
- Semester 2

Year
- 2021/2

Credits
- 15.0

The general aim of this module is to introduce students to semigroup theory, which is the study of sets with one associative binary operation defined on them. In the process, the common aims and concerns of abstract algebra will be emphasised and illustrated by drawing comparisons between semigroups, groups and rings.

Timetable
- 1pm Monday, Thursday, Friday

Lecturer
- Prof Nik Ruskuc

Prerequisites
- Before taking this module you must pass MT3505 or pass MT4003
Antirequisites
   You cannot take this module if you take MT5823

Lectures and tutorials
   2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment
   2-hour written examination = 100%

Module coordinator
   Prof Nik Ruskuc

MT5863 runs in alternate years.

Additional background to module

Semigroups are one of the most fundamental algebraic objects; their theory underpins several areas of mathematics and computer science. In this course you will study the fundamental aspects of the theory of semigroups, such as Green’s relations and lemma, the Rees Theorem, congruences, and presentations.

Intended Learning Outcomes

By the end of this module students will be able to

- Encounter the aspects of the theory of semigroups that are shared by many areas in universal algebra: free semigroups, homomorphisms, congruences, isomorphism theorems, subsemigroups, presentations, and so on
- Develop a good understanding of the fundamental aspect of the theory that are unique to the semigroups, including Green’s relations, Green’s lemma, the Rees theorem
- Learn to determine the structure of an arbitrary semigroup defined by a finite generating set
- Develop a familiarity with several standard examples of semigroups, such as the full transformation monoids, rectangular bands, Rees 0-matrix semigroups, left and right zero semigroups, semigroups defined by presentations, and so on
- Study several special classes of semigroup: simple, inverse, regular, or Clifford semigroups
- Study some methods of constructing new semigroups from old via, for instance, direct products

Syllabus

- Definition and first examples
- Homomorphisms and isomorphisms
- Congruences and quotients
Groups are important mathematical objects that arise in many contexts since they encode the symmetry appearing within any particular setting. This is an area of current research interest in the School and this expertise determines the choice of topics covered in this module. The overall aim of the module is to build on the foundations established in MT4003 and to take students deeper into this important and beautiful branch of mathematics. It will introduce students to advanced techniques used to handle and classify groups.

Timetable
10am, Monday (odd weeks), Wednesday, Friday

Lecturer
Dr Martyn Quick

Prerequisites
Before taking this module you must pass MT4003

Antirequisites
You cannot take this module if you take MT5824

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 tutorial (x 9 weeks), 1 examples class (x 9 weeks)

Assessment
2-hour Written Examination = 100%

Module coordinator
Dr M Quick

This module runs each year.
This module extends the foundations established in MT4003 and takes students deeper into the theory of groups. It will introduce students to advanced techniques used to work with, handle, and classify groups, and expose the student to some groups and/or ideas from the forefront of current research in group theory.

**Intended Learning Outcomes**

By the end of this module students will be able to

- Demonstrate an understanding of core group theory topics including actions, subgroups, quotient groups, and extensions
- Be familiar with, and able to work with, more complicated groups than just those appearing at the 4000 level
- Be able to produce complete theoretical arguments (proofs) which establish general properties of groups
- Be able to state and to use some advanced theorems in group theory
- Apply the above competencies to discern properties of given groups and to demonstrate an understanding of advanced methods by being able to apply them to discern key features of given groups
- Obtain and be able to demonstrate a capacity in problem solving in group theory

**Reading List**

- Peter J. Cameron, *Permutation Groups*, CUP 1999

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**MT5865 Measure and Probability Theory**

- Semester
  - Semester 1
- Year
  - 2021/2
- Credits
15.0

This module introduces some of the powerful techniques and ideas of modern mathematical analysis and mathematical probability theory that are important both in analysis in its own right and in its many applications in mathematics and science. The module will include topics such as: measure theory, the mathematical foundations for probability theory, law of large numbers. Mathematical analysis and the use of probabilistic methods in analysis is one of the active research areas within the School, and the choice of topics will reflect current activity.

Timetable
   11am Monday (odd weeks), Wednesday, Friday
Lecturer
   Prof Lars Olsen
Prerequisites
   Before taking this module you must pass MT3502
Antirequisites
   You cannot take this module if you take MT5825
Lectures and tutorials
   2.5 lectures (x 10 weeks), 1 tutorial (x 9 weeks)
Assessment
   2-hour Written Examination = 100%
Module coordinator
   Prof L O R Olsen

This module runs each year.

Additional background to module

This module will familiarise students with measures. The student will see many examples of measures, and some of the more sophisticated theory of measure theory will be covered, including, for example, monotone convergence theorem and the dominated convergence theorem. The student will also see the Lebesgue spaces L^p. Finally, the ideas from measure theory will be applied to probability and the student will see how probabilistic techniques can be applied to solve non-trivial problems in analysis.

Intended Learning Outcomes

By the end of this module students will be able to

- Understand the notion of a sigma-algebra and a measure
- Understand the definition of the Lebesgue integral
Understand and appreciate the convergence results associated with the Lebesgue integral, including, the monotone convergence theorem and the dominated convergence theorem

Understand the definition and the theory of the Lebesgue spaces L^p

Understand probability theory’s measure theoretical foundations

Understand key results from probabilistic measure theory, including, law of large numbers and random series

Syllabus

- Sigma-algebras and measures
- Measurable functions
- The Lebesgue integral and convergence theorems
- L^p spaces
- Construction of measures and Caratheodory's theorem
- Basic notions from measure theoretic probability
- The weak law of large numbers; the strong law of large numbers
- Random series
- The law of the iterated logarithm

Reading list


Print text supplementary reading material


MT5866 Probability Theory

Semester

- Semester 1

Year

- 2022/3

Credits

- 15.0

This module will develop probability theory in a rigorous manner to access some of the big theorems of the subject, such as the laws of large numbers, the central limit theorem, and the martingale convergence theorem. The module will have the flavour of mathematical analysis, but there are applications across the mathematical sciences in areas such as statistics, game theory, statistical physics and mathematical biology.
Timetable

12 noon Mondays (even weeks), Tuesdays and Thursdays

Lecturer

Prerequisites

Before taking this module you must pass MT2504 and pass MT3502

Antirequisites

Lectures and tutorials

2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment

2-hour Written Examination = 100%

Module coordinator

This module runs in alternate years.

Additional Background to Module

This module will develop probability theory in a rigorous manner to access some of the big theorems of the subject, such as the laws of large numbers, the central limit theorem, and the martingale convergence theorem. The module will have the flavour of mathematical analysis, but there are applications across the mathematical sciences in areas such as statistics, game theory, statistical physics and mathematical biology.

Intended Learning Outcomes

- Understand the rigorous foundations of probability theory on a finite or continuous sample space.
- Understand key properties of random variables, including expectations and notions of convergence of sequences of random variables.
- Apply important techniques in probability theory such as inequalities, moments, and characteristic functions.
- Appreciate and apply some of the major theorems of probability such as the laws of large numbers, the martingale convergence theorems, the central limit theorem and the renewal theorem, along with careful proofs of such results.
Mathematical logic is a branch of mathematics which attempts to subject mathematical reasoning itself to a rigorous mathematical treatment, while sets provide a language in which underpins much of contemporary mathematics. In this module we will study both, as well as their interactions. The topics will include predicate calculus, cardinals and ordinals, axiomatic systems for set theory, the beginnings of recursion theory, and the major theorems of mathematical logic, such as compactness and completeness theorems for predicate calculus, as well as Goedel's incompleteness theorem for Peano arithmetic. We will also discuss the ramifications of these results in other parts of mathematics and beyond.

Timetable
12 noon Mondays (odd weeks), Wednesdays and Fridays

Lecturer

Prerequisites
Before taking this module you must pass at least two of: MT3505, MT4003, MT4004, MT4512, MT4514, MT4515, MT4526

Antirequisites
You cannot take this module if you take CS3050

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment
2-hour Written Examination = 100%

Module coordinator

This module runs in alternate years.

Additional Background to Module

Mathematical logic is a branch of mathematics which attempts to subject mathematical reasoning itself to a rigorous mathematical treatment, while sets provide a language in which underpins much of contemporary mathematics. In this module we will study both, as well as their interactions. The topics will include predicate calculus, cardinals and ordinals, axiomatic systems for set theory, the beginnings of recursion theory, and the major theorems of mathematical logic, such as compactness and completeness theorems for predicate calculus, as well as
Goedel's incompleteness theorem for Peano arithmetic. We will also discuss the ramifications of these results in other parts of mathematics and beyond.

**Intended learning outcomes**

- Demonstrate an understanding of the key concepts in mathematical logic and set theory, such as first order formulas, models, satisfiability, formal proofs, cardinals, ordinals and recursive functions.
- Produce coherent theoretical arguments (proofs) which establish properties for the above concepts and their relationships with each other.
- Understand the content and importance of major theorems such as the compactness theorem, completeness theorem, Goedel's Incompleteness Theorem and Zorn's Lemma.
- Be able to use the above results in analysing specific examples of mathematical theories and in problem-solving.

- **MT5870 Hyperbolic Geometry**

  Semester
  Semester 2
  Year
  2022/3
  Credits
  15.0

We study two dimensional hyperbolic space, which is a fundamental example of a non-Euclidean metric space. Hyperbolic space has a rich structure and many counter intuitive properties and this module will focus on the geometry of this space, including a detailed study of the geodesic structure, the group of isometries, and the actions of Fuchsian groups which lead to beautiful tilings and fractal limit sets. We will combine ideas from analysis, geometry and group theory, with a strong emphasis on visual intuition.

**Timetable**
- 10am, Monday (odd weeks), Wednesday, Friday

**Lecturer**

**Prerequisites**
- Before taking this module you must pass MT2505 and pass MT3502 and pass MT3503

**Antirequisites**
- You cannot take this module if you take MT5828 or take MT5830
Lectures and tutorials
   2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)
Assessment
   100% exam.
Module coordinator

MT5870 runs in alternate years.

Additional background to module

We study 2-dimensional hyperbolic space, which provides a fundamental example of non-Euclidean geometry. Hyperbolic space has a rich structure and many counter intuitive properties and this module will focus on the geometry of this space, including a detailed study of the geodesic structure, the group of isometries, and the actions of Fuchsian groups which lead to beautiful tilings and fractal limit sets. We will combine ideas from analysis, geometry and group theory, with a strong emphasis on visual intuition.

Intended Learning Outcomes

By the end of this module students will be able to

- Understand the Poincaré disc and upper half plane as models of 2-dimensional hyperbolic space
- Understand the basic geometry of hyperbolic space and be able to perform calculations involving, for example, geodesics, hyperbolic circles, and hyperbolic triangles
- Understand the group of isometries and be able to classify isometries by fixed points, trace, and standard form
- Understand and work with Fuchsian groups
- Appreciate the interplay between Fuchsian groups and tilings of hyperbolic space
- Understand and be able to derive several properties of limit sets of Fuchsian groups

Syllabus

- The Poincaré disc and upper half plane as models of 2D hyperbolic space
- Basic geometry of hyperbolic space (geodesic structure, hyperbolic circles, and hyperbolic triangles)
- Group of isometries, group actions
- Fuchsian groups, fundamental domains
Galois Theory is one of the most beautiful areas of mathematics, establishing a remarkable connection between the theory of polynomial equations and their roots, and group theory. The subject brings together ideas from the theory of groups and fields in a powerful way, culminating in the Fundamental Theorem of Galois Theory and Galois’s Great Theorem. A consequence will be the demonstration that there is no general formula for the solution of quintic equations. There are many additional applications of this theory, for example, the demonstration that certain ruler and compass constructions are impossible.

Timetable
11am Monday (odd weeks), Wednesday, Friday

Lecturer

Prerequisites
Before taking this module you must pass MT3505

Antirequisites
You cannot take this module if you take MT5826 or take MT5836

Lectures and tutorials
2.5 lectures (x 10 weeks), 1 tutorial (x 10 weeks)

Assessment
100% exam.

Module coordinator

MT5876 runs in alternate years.
Galois Theory is a subject with considerable history, dating back to the work of Évariste Galois (1811-1832). It is primarily concerned with the solution of polynomial equations by radicals; that is, formulae analogous to the familiar one for quadratic equations. We study field extensions and associate a group, called the Galois group, to each field extension. Under sufficient conditions, a strong theorem - the Fundamental Theory of Galois Theory - says that there is a link between the structure of this group and the behaviour of the field extension. In particular, when the field extension is obtained by adjoining the roots of a particular polynomial, Galois's Great Theorem tells us that one can express these roots by the required formula precisely when the Galois group is a soluble group.

Intended Learning Outcomes

By the end of this module students will be able to

- Work with fields and field extensions, construct the field obtained by adjoining a root of a polynomial, and produce theoretical arguments (proofs) about the resulting extension
- Define what is meant by the degree of a field extension, what it means for a field extension to be algebraic, simple, normal, and separable, and be able to produce theoretical arguments concerning these objects
- Work with finite fields and theorems concerning their existence, uniqueness (for each order up to isomorphism), and the fact that their multiplicative group is cyclic, and use these properties to solve problems
- Define the Galois group of a field extension, define the Galois correspondence between the intermediate fields and the subgroups of the Galois group
- State the Fundamental Theorem of Galois Theory and be able to use it to solve problems about field extensions and Galois groups
- Define what is meant by a radical extension, to use this concepts in the context of solving polynomial equations, and to construct polynomials that cannot be solved by radicals

MT5877 Ergodic Theory and Dynamical Systems

Semester
Semester 2
Year
2021/2
Credits
15.0
This module introduces the modern ergodic theory approach to understanding chaotic dynamical systems. Topics include recurrence, consequences of ergodicity, entropy, the structure of the space of invariant measures and unique ergodicity. This will give students an insight into a thriving field of mathematics, which is at the core of the research interests of many faculty in the Pure Division in the School of Mathematics and Statistics.

Timetable
   9am Monday (even), Tuesday, Thursday
Lecturer
   Dr Mike Todd
Prerequisites
   Before taking this module you must pass MT5865 or pass MT5825
Antirequisites
   You cannot take this module if you take MT5837
Lectures and tutorials
   2.5 lectures (weeks 1-10), 1 tutorial (weeks 2-11)
Assessment
   2-hour written examination = 100%
Module coordinator
   Dr M J Todd

MT5877 runs in alternate years.

Additional background to module

Chaotic dynamical systems are by definition difficult to analyse, and one of the most powerful approaches is to view the system through its associated measures (MT5825/5865 is a prerequisite here). Then the system can be characterised via its average properties (with respect to that measure), its statistical limit laws (mixing properties, probabilistic theorems), as well as which measures the system supports. This course introduces dynamical systems and their associated measures and then covers basic recurrence theorems. There will also be an extensive discussion of entropy, which provides an important characterisation of the system (a measure of how chaotic the system is).

Intended Learning Outcomes

By the end of this module students will be able to

- Be able to work with some simple dynamical system models
Understand how invariant measures can be used to explain the recurrence properties of a dynamical system

Appreciate ergodicity: as a building block for understanding all the average behaviours of a system, and the classical theorems (e.g. Birkhoff's Ergodic Theorem) associated to it

Be able to define, work with and develop an intuitive understanding of, entropy

Understand the fundamental structure of the set of invariant measures

Syllabus
- Introduction to basic dynamical systems
- Invariant measures
- Poincaré Recurrence Theorem
- Birkhoff's Ergodic Theorem and applications
- Measure preserving transformations
- Methods for finding entropy
- Applications of entropy
- The space of invariant measures

Print text supplementary reading material
- An Introduction to Ergodic Theory, P. Walters, Springer
- Ergodic Theory, K. Petersen, Cambridge University Press
- Ergodic Theory with a View Towards Number Theory, M. Einsiedler and T. Ward, Springer

MT5991 Professional Skills for Mathematical Scientists

Semester
  - Full Year
Year
  - 2021/2
Credits
  - 30.0

This module encompasses a range of skills, both generic and topic specific, together with taught components aimed at providing an appreciation of both breadth and depth of research areas in Pure or Applied Mathematics. The precise programme of study, together with the identification of the relevant software expertise required, will be determined in consultation with the student's supervisor.

Timetable
  - To be arranged.
Lecturer
Team Taught
Prerequisites

Antirequisites

Lectures and tutorials
Varies. Typically 1 project supervision per week over whole year.

Assessment
Coursework = 100%

Module coordinator
Prof J D Mitchell

Before enrolling on this module you must complete a Letter of Agreement (MT5991 letter of agreement (PDF) , MT5991 letter of agreement (Word) ).

Additional background to module

The Professional Skills for Mathematical Scientists is a specialised module for students who excel at an advanced level (typically final year MMath/MPhys students or MSc students) and where alternative modules in the School are less appropriate as part of the overall balance in their degree programme. It may be suitable if you are particularly interested in an area of mathematics/statistics that is not part of our main module offering but essential for future studies (e.g. an MSc or PhD), or there is a good reason why you have not been able to take a taught module in the area.

It is the responsibility of each individual student to arrange a supervisor in the module. A first step is to speak with staff who work in the relevant area and seeing if any have availability, before (should discussions evolve positively) narrowing things down further via the Letter of Agreement. Advisers of Study or the Director of Teaching (for undergraduate students)/Director of Postgraduate Studies (for postgraduate students) can provide general advice about which staff have relevant expertise in a particular subject area.

Intended Learning Outcomes

By the end of this module students will be able to

- Demonstrate a knowledge and understanding of an advanced area of mathematics/statistics
- Construct and evaluate logical arguments in the area of advanced study
Present mathematics/statistics in the area of advanced study in an appropriate manner
Demonstrate competence in independent learning and time management

- **ID5059 Knowledge Discovery and Datamining**

  Semester  
  Semester 2  
  Year  
  2021/2  
  Credits  
  15.0

Contemporary data collection can be automated and on a massive scale e.g. credit card transaction databases. Large databases potentially carry a wealth of important information that could inform business strategy, identify criminal activities, characterise network faults etc. These large scale problems may preclude the standard carefully constructed statistical models, necessitating highly automated approaches. This module covers many of the methods found under the banner of Datamining, building from a theoretical perspective but ultimately teaching practical application. Topics covered include: historical/philosophical perspectives, model selection algorithms and optimality measures, tree methods, bagging and boosting, neural nets, and classification in general. Practical applications build sought-after skills in programming (typically R, SAS or python).

**Timetable**  
11.00 am Mon (odd weeks), Wed and Fri

**Lecturer**  
Team Taught

**Prerequisites**

**Antirequisites**  
You cannot take this module if you take CS5014

**Lectures and tutorials**  
Lectures, seminars, tutorials and practical classes.

**Assessment**  
2-hour Written Examination = 60%, Coursework = 40%

**Module coordinator**

In 2021/22 this interdisciplinary module will be taught by the School of Mathematics and Statistics.
Intended Learning Outcomes

By the end of this module students will be able to

- Understand the mathematics underpinning common machine-learning/data-mining methods, including parameter estimation
- Determine what models are applicable for different data and objectives
- Understand complex regressions from the perspective of basis functions, tree methods, boosting/bagging/ensemble model variants, neural networks, deep-learning, and other selected method
- Conduct hyperparameter-tuning/model-selection as appropriate to the model
- Manipulate data, fit models, and summarise/display their results/performance and objectively compare models in R, Python or other suitable language
- Conduct comprehensive analysis of large real-world data, within a group, covering: data preparation; model fitting, critique and refinement; and presentation of results to a range of audiences