This is a list of the 3000-level modules that were available to students during the 2019-2020 academic year. The School's courses remain broadly the same from year to year, but this list of module offerings is for illustration purposes only and does not constitute a guarantee of the specific modules, module content or timetabling to be offered in future years.

3000-level modules

MT3501 Linear Mathematics 2
MT3502 Real Analysis
MT3503 Complex Analysis
MT3504 Differential Equations
MT3505 Algebra: Rings and Fields
MT3506 Techniques of Applied Mathematics
MT3507 Mathematical Statistics
MT3508 Applied Statistics
MT3802 Numerical Analysis
MT3832 Mathematical Programming

MT3501 Linear Mathematics 2

Credits 15.0

Semester 1

Academic year 2019/20

Timetable 12.00 noon Mon (even weeks), Tue and Thu

Description This module continues the study of vector spaces and linear transformations begun in MT2501. It aims to show the importance of linearity in many areas of mathematics ranging from linear algebra through to geometric applications to linear operators and special functions. The main topics covered include: diagonalisation and the minimum polynomial; Jordan normal form; inner product spaces; orthonormal sets and the Gram-Schmidt process; adjoint and self-adjoint operators.
**Prerequisites**
MT2001 or MT2501

**Antirequisites**
Lectures and tutorials
2.5 lectures (weeks 1 - 10) and 1 tutorial (weeks 2 - 11).

**Assessment**
2-hour Written Examination = 90%, Coursework = 10%

**Module coordinator**
Prof J D Mitchell

**Lecturer**
Prof J D Mitchell

Continuous assessment

- Assessed tutorial-style questions: 10% of final mark.

**Syllabus**

- Vector spaces: subspaces, spanning sets, linear independent sets, bases.
- Linear transformations: rank, nullity, general form of a linear transformation, matrix of a linear transformation, change of basis.
- Direct sums, projection maps.
- Diagonalisation of linear transformations: eigenvectors and eigenvalues, eigenspaces, characteristic polynomial, minimum polynomial, characterisations of diagonalisable transformations.
- Jordan normal form: method to determine the Jordan normal form.
- Inner product spaces: orthogonality, associated inequalities, some examples of infinite-dimensional inner product spaces, orthonormal bases, Gram-Schmidt process, orthogonal complements, applications.

**Assumed knowledge**

- Familiarity with solving systems of linear equations.
- Matrices, their basic properties, determinants and the method of finding the inverse of a matrix (provided it has non-zero determinant).
- Students will have met the definition of a vector space, basis, linear transformation, and their properties. These will be revised quite rapidly (and more properties discussed) at the start of the course.

**Reading list**

MT3502  Real Analysis

Credits  15.0

Semester  1

Academic year  2019/20

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

Description  This module continues the study of analysis begun in the 2000-level module MT2502 Analysis. It considers further important topics in the study of real analysis including: integration theory, the analytic properties of power series and the convergence of functions. Emphasis will be placed on rigorous development of the material, giving precise definitions of the concepts involved and exploring the proofs of important theorems. The language of metric spaces will be introduced to give a framework in which to discuss these concepts.

Prerequisites  MT2502

Antirequisites

Lectures and tutorials  2.5-hours of lectures and 1 tutorial.

Assessment  2-hour Written Examination = 90%, Class Test = 10%

Module coordinator  Prof K J Falconer

Lecturer  Prof K J Falconer

Continuous assessment

- 50-minute class test: 10% of final mark.

Syllabus

- Countable and uncountable sets, including standard examples, basic properties, methods for showing sets are countable or uncountable.
- Review of convergence of sequences and continuity of real functions; uniform continuity.
- Riemann integration, definition in terms of lower and upper sums, basic properties, integrability of continuous and monotonic functions; integral of the uniform limit of a sequence of functions; Fundamental Theorem of Calculus.
- Power series, radius of convergence, differentiation and integration of power series.
- Introduction to convergence and continuity in normed and metric spaces, examples, including
uniform convergence and $L^1$ convergence.

Reading list

- David Brannan, A First Course in Mathematical Analysis, CUP, 2006.
- DJH Garling, A Course in Mathematical Analysis, Vol.1, CUP, 2014. (More advanced)

MT3503  Complex Analysis

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<td>Timetable</td>
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This module aims to introduce students to analytic function theory and applications. The topics covered include: analytic functions; Cauchy-Riemann equations; harmonic functions; multivalued functions and the cut plane; singularities; Cauchy's theorem; Laurent series; evaluation of contour integrals; fundamental theorem of algebra; Argument Principle; Rouche's Theorem.

Prerequisites  MT2502 or MT2503 or MT2001

Antirequisites

Lectures and tutorials  2.5 lectures (weeks 1 - 10) and 1 tutorial (weeks 2 - 11).

Assessment  2-hour Written Examination = 90%, Coursework = 10%

Module coordinator  Dr M R Quick

Lecturer  Dr M R Quick

Syllabus

- Review of complex numbers
- Holomorphic functions
- Contour integrals and Cauchy's Theorem
- Consequences of Cauchy's Theorem, including Liouville's Theorem, the Fundamental Theorem of Algebra, and Taylor's Theorem
Harmonic functions
Singularity, poles and residues: Laurent's Theorem, classification of isolated singularities, and Cauchy's Residue Theorem
Application of contour integration: calculation of various integrals and infinite sums
Complex logarithms and related multfunctions: branch cuts
Counting zeros and poles: Rouché's Theorem and the Argument Principle

Reading list

MT3504  Differential Equations

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Description
The object of this module is to provide a broad introduction to analytical methods for solving ordinary and partial differential equations and to develop students' understanding and technical skills in this area. This module is a prerequisite for several other Honours options. The syllabus includes: existence and uniqueness of solutions to initial-value problems; non-linear ODE's; Green's functions for ODE's; Sturm-Liouville problems; first order PDE's; method of characteristics; classification of second order linear PDE's; method of separation of variables; characteristics and reduction to canonical form.

Prerequisites
MT2001 or MT2503

Antirequisites

Lectures and tutorials
2.5 lectures (weeks 1 - 10) and 1 examples class (week 2 - 11).

Assessment
Written Examination = 100% (2-hour final exam = 90%, class test = 10%)

Module coordinator
Prof D G Dritschel

Lecturer
Prof D G Dritschel, Dr A Wilmot-Smith

Syllabus
- Existence and uniqueness of solutions to initial-value problems.
- Non-linear ordinary differential equations.
- Green’s functions for ordinary differential equations.
- Sturm-Liouville problems.
- First-order partial differential equations; methods of characteristics.
- Classification of second-order partial differential equations; method of separation of variables.
- Characteristics and reduction to canonical form.

Reading list


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**MT3505  Algebra: Rings and Fields**

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**Description**

This module continues the study of algebra begun in the 2000-level module MT2505 Abstract Algebra. It places emphasis on the concept of a ring and their properties, which give insight into concepts of factorisation and divisibility. Important examples such as polynomial rings will be used to motivate and illustrate the theory developed.

**Prerequisites**

MT2505

**Antirequisites**

MT4517

**Lectures and tutorials**

2.5 hours of lectures and 1 tutorial.

**Assessment**

2-hour Written Examination = 90%, Coursework = 10%

**Module coordinator**

Dr S Huczynska

**Lecturer**

Dr S Huczynska

**Continuous assessment**

Short piece of work examining some of the topics developed in the module: 10% of final mark.
Syllabus

- Rings: definitions, examples (integers, modulo arithmetic, polynomial rings, etc.), definition of a field and its characteristic.
- Subrings, the prime subfield of a field, ideals, homomorphisms, quotient rings, the Isomorphism Theorems.
- Integral domains, field of fractions.
- Euclidean domains, polynomial rings (over fields) as Euclidean domains, Euclidean algorithm, greatest common divisors.
- Prime ideals, maximal ideals, their links to the quotient rings.
- The Chinese Remainder Theorem. Applications of rings to number theory.
- Prime ideals and maximal ideals in Euclidean domains, and in particular in polynomial rings.
- Principal ideal domains, examples.
- Unique factorisation domains, theorem that if $R$ is a UFD, then $R[X]$ is a UFD.

Reading list


MT3506  Techniques of Applied Mathematics

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Description

Differential equations are of fundamental significance in applied mathematics. This module will cover important and common techniques used to solve the partial differential equations that arise in typical applications. The module will be useful to students who wish to specialise in Applied Mathematics in their degree programme.

Prerequisites

MT2506 and MT3504

Antirequisites

PH3081

Lectures and tutorials

2.5 hours of lectures and 1 tutorial.
Assessment

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Module coordinator

<table>
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<tr>
<th>Module coordinator</th>
<th>Dr R K Scott</th>
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Lecturer

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<th>Lecturer</th>
<th>Dr D Rees-Jones, Dr R K Scott</th>
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Syllabus

- Modelling and interpretation (generating ordinary and partial differential equations).
- Ordinary differential equations resulting from separation of variables of partial differential equations (Laplacian operator in cylindrical and spherical coordinates).
- Frobenius methods for regular singular points.
- Special functions, including Bessel functions, Legendre (and associated) functions and Airy functions, Hermite, Laguerre, Heaviside and Delta functions.
- Green's function solutions for partial differential equations; examples of applications (e.g., Poisson's Equation for self-gravitation or electrostatics).
- Vector calculus revision and application to physical problems: e.g., solutions to $\nabla p = F$ (where curl $F = 0$), curl $B = j$ (Biot-Savart law), $\text{div} E = \rho_c$, $B = \text{curl} A$ (using Stokes' Theorem).
- Application to conservation laws (e.g., mass continuity as physical problem).

Reading list


MT3507  Mathematical Statistics

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Together with MT3508, this module provides a bridge between second year and Honours modules in statistics. It will provide students with a solid theoretical foundation on which much of more advanced statistical theory and methods are built. This includes probability generating functions and moment generating functions, as well as widely used discrete distributions (binomial, Poisson, negative binomial and multinomial) and continuous distributions (gamma, exponential, chi-squared, beta, t-distribution, F-distribution, and multivariate normal). It will also provide a foundation in methods of statistical inference.
(maximum likelihood and Bayesian) and model selection methods based on information theory (AIC and BIC).

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<tr>
<th>Prerequisites</th>
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<td>Module coordinator</td>
<td>Prof S T Buckland</td>
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<td>Lecturer</td>
<td>Prof S T Buckland</td>
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Continuous assessment

50-minute class test: 10% of final mark

Syllabus

- Discrete data and distributions: Recap of probability generating functions; Binomial data: normal approximation, confidence intervals, dispersion test, testing equality of two binomial proportions.
- Poisson data: point estimation, confidence intervals, dispersion test, comparison of two Poisson counts.
- Further standard discrete distributions: negative binomial, multinomial.
- Continuous distributions: Recap of moment generating functions; Distribution of a function of a single random variable, function of several random variables.
- Some standard continuous distributions: gamma (including exponential and chi-squared), beta, t, F.
- Multivariate normal distribution.
- Likelihood-based methods: The likelihood function; Maximum likelihood vs Bayesian methods.
- Maximum likelihood estimators: properties, variance and interval estimation; Sufficient statistics.
- Bayes' Theorem, prior and posterior distribution, conjugate priors, credible intervals; Information criteria: AIC and BIC.
- General (normal) linear model: The normal equations; Hypothesis testing.

Reading list

- M.H. DeGroot & M.J. Schervish, Probability and Statistics, 4th edn
- G.M. Clarke & D. Cooke, A Basic Course in Statistics, 5th edn
- M. Fisz, Probability Theory & Mathematical Statistics
- G. Casella & R.L. Berger, Statistical Inference, 2nd edn
- J.G. Kalbfleisch, Probability and Statistical Inference, volume 2
MT3508  Applied Statistics

Credits          15.0
Semester         2
Academic year    2019/20
Timetable        12.00 noon Mon (even weeks), Tue & Thu

Description
Together with MT3507, this module provides a bridge between second year and Honours modules in statistics. It deals with the application of statistical methods to test hypotheses and draw inferences from data. This includes a number of nonparametric methods and statistical tests (goodness-of-fit tests and tests of independence). Inference methods include model fitting by least squares and maximum likelihood, and variance estimation by means of the information matrix and the bootstrap. The framework of the generalised linear model is presented covering parameter estimation, deviance, model selection and diagnostics. Further applications include multiple regression, analysis of variance and the (normal) linear model.

Prerequisites  MT2508
Antirequisites

Lectures and tutorials
2.5 hours of lectures and 1 tutorial.

Assessment
2-hour Written Examination = 90%, Coursework (Project) = 10%

Module coordinator
Prof D L Borchers

Lecturer
Prof D L Borchers

Continous assessment

Computer-based project using the package R: 10% of final mark

Syllabus
- Nonparametric methods and goodness-of-fit: Types of data; Recap of permutation and randomization tests; Sign test.
- Wilcoxon signed ranks test; Mann–Whitney test.
- Chi-squared tests of homogeneity and independence.
- Model fitting and quantifying precision: Least squares.
- Maximum likelihood; Estimating variance using the information matrix.
Nonparametric bootstrap; Parametric bootstrap.
Statistical modelling: Multiple regression; Analysis of variance.
Factorial experiments; The general (i.e., normal) linear model.
Brief summary of GLMs and GAMs, and how to fit them.

Reading lists

- S. Siegel & N.J. Castellan Jr., Nonparametric Statistics for the Behavioral Sciences, 2nd edn
- W.J. Conover, Practical Nonparametric Statistics, 3rd edn

MT3802 Numerical Analysis

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Description

The module will introduce students to some topics in numerical analysis, which may include methods of approximation, iterative methods for solving systems of linear equations, numerical techniques for differential equations.

Prerequisites
MT2501

Antirequisites

Lectures and tutorials
2.5 lectures (weeks 1 - 10) and 1 tutorial (weeks 2 - 11).

Assessment
2-hour Written Examination = 70%, Coursework = 30%

Module coordinator
Dr A P Naughton

Lecturer
Dr A P Naughton

Syllabus

- Norms (ways to measure errors).
- Iterative methods to solve linear systems of equations.
- Approximations to functions.
- Best approximations.
Numerical techniques for differential equations.

Assumed knowledge

It will be assumed that students have a good knowledge of basic matrix methods (inversion, multiplication, etc.).

Reading list


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**MT3832 Mathematical Programming**

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**Description**

The aim of this module is to introduce students to the formulation and solution of various linear programming problems. The subject matter will be illustrated by applying the methods of solution to real examples. The syllabus includes: formulation of linear problems; solution graphically and by simplex algorithm; sensitivity analysis; duality; transportation and transshipment; the assignment problem.

**Prerequisites**

MT2001 or MT2501 or (MT1002 and MN2002)

**Antirequisites**

**Lectures and tutorials**

2.5 lectures (weeks 1 - 10) and 0.5 tutorial (weeks 2 - 11).

**Assessment**

2-hour Written Examination = 100%

**Module coordinator**

Dr M Papathomas

**Lecturer**

Dr M Papathomas

MT3832 ran in alternate years. It will be withdrawn after 2019/20.