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Course Regulations for Year 3

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3)

MATHEMATICS BSC. G100

Normal Load = 120 CATS. Maximum Load = 150 CATS.

Candidates for Honours are required to take:Modules totalling at least 57 CATS credits from List A (including at least 45 CATS of modules with codes beginning MA3 or ST318), and an appropriate number of modules selected from List B, such that the total number of credits from List B and Unusual Options combined shall not exceed 66 CATS (not including Level 7 MA and ST coded modules where Level 7 are 4th year and MSc. level modules).

Certain students who scored a low maths average at the end of the second year will not be permitted to take more than 132 CATS, but will also offered the opportunity to take MA397 Consolidation to improve their chances of securing an honours degree at the end of the 3rd year. This is a decision of the Second Year Exam Board.

MASTER OF MATHEMATICS MMATH G103

Normal Load = 120 CATS. Maximum Load = 150 CATS.

Students are required to take at least 90 CATS from Lists A and C. Although it is not a requirement to take any List C modules in the 3rd year, note that G103 students must take, in their third and fourth years combined, at least 105 CATS from the Core (MA469 Project) plus Lists C and D.

Third year students obtaining an end of year average (with adjustment where there is overcatting) less than 55% and/or less than 55% in their best 90 CATS of List A and List C modules, will normally be considered for the award of a BSc. and not permitted to continue into the 4th year.

Comments

Students should note that the *exams for Term 1 Mathematics modules*, including some reading modules, take place at the *beginning of Term 3*.

The second year modules below are available as third year List A options worth 6 or 12 CATS if not taken in Year 2. However, not all these modules are guaranteed to take place every year.

Each List A Year 3 Mathematics module should have a Support Class timetabled in weeks 2 to 10 of the same Term. This is your opportunity to bring the examples you have been working on, to compare progress with fellow students and, where several people are stuck or confused by the same thing, to get guidance from the graduate student in charge. When more than 30 people want to come a second weekly session can be arranged.
It is advisable to check the timetable as soon as possible for two reasons. Firstly, the timing of a course may be unavoidably changed and this page not updated to reflect that yet. Secondly, to guard against clashes. Some will be inevitable, but others may be avoided if they are noticed sufficiently well in advance. This is particularly important if you are doing a slightly unusual combination of options, and if you intend to take options outside the Science Faculty. Pay particular attention to the possibility that modules advertised here as in Term 2 may have been switched to Term 1. Check the Timetable at the start of term.

For a full list of available modules see the relevant course regulation page.

Maths Modules

Note: Term 1 modules are generally examined in the April exam period directly after the Easter vacation and Term 2 modules in the Summer exam period during weeks 4 to 6.

hide

Term	Code	Module	CATS	List
Term 1	MA241	Combinatorics	12	List A
	MA243	Geometry	12	List A
	MA359	Measure Theory	15	List A
	MA377	Rings and Modules	15	List A
	MA390	Topics in Mathematical Biology	15	List A
	MA397	Consolidation	7.5	Unusual (by invite only)
	MA3D5	Galois Theory	15	List A
	MA3D9	Geometry of Curves and Surfaces	15	List A
	MA3E5	History of Mathematics	15	List A
	MA3F1	Introduction to Topology	15	List A
	MA3G7	Functional Analysis I	15	List A
	MA3H3	Set Theory	15	List A
	MA3H5	Manifolds	15	List A
	MA3J3	Bifurcations, Catastrophes and Symmetry	15	List A
	MA3J4	Mathematical modelling with PDEs	15	List A
Terms 1 & 2	MA250	Introduction to Partial Differential Equations (weeks 6 to 10, 15 to 19)	12	List A
	MA372	Reading Module	15	List A
	MA395	Essay	15	List A
Term 2	MA222	Metric Spaces	12	List A
	MA228	Numerical Analysis (wks 15-19)	6	List A
	MA252	Combinatorial Optimization	12	List A
	MA254	Theory of ODEs	12	List A
	MA257	Introduction to Number Theory	12	List A
	MA3A6	Algebraic Number Theory	15	List A
	MA3B8	Complex Analysis	15	List A
	MA3D1	Fluid Dynamics	15	List A
	MA3D4	Fractal Geometry	15	List A
	MA3E1	Groups and Representations	15	List A
	MA3E7	Problem Solving	15	List B
	MA3F2	Knot Theory	15	List A

	MA3G1	Theory of PDEs	15	List A
	MA3G6	Commutative Algebra	15	List A
	MA3G8	Functional Analysis II	15	List A
	MA3H0	Numerical Analysis and PDEs	15	List A
	MA3H2	Markov Processes and Percolation Theory	15	List A
	MA3H6	Algebraic Topology	15	List A
	MA3H7	Control Theory	15	List A
	MA3J2	Combinatorics II	15	List A
Term 3	MA209	Variational Principles	6	List A

Interdisciplinary Modules (IATL)

Second, third and fourth-year undergraduates from across the University faculties are now able to work together on one of IATL's 12-15 CAT interdisciplinary modules. These modules are designed to help students grasp abstract and complex ideas from a range of subjects, to synthesise these into a rounded intellectual and creative response, to understand the symbiotic potential of traditionally distinct disciplines, and to stimulate collaboration through group work and embodied learning.

Maths students can enrol on these modules as an Unusual Option, you can register for a maximum of TWO IATL modules but also be aware that on many numbers are limited and you need to register an interest before the end of the previous academic year. Contrary to this is IL006 Challenges of Climate Change which replaces a module that used to be PX272 Global Warming and is recommended by the department, form filling is not required for this option, register in the regular way on MRM.

Please see the IATL page for the full list of modules that you can choose from, for more information and how to be accepted onto them, but some suggestions are in the table below:

hide

Term	Code	Module	CATS	List
Term 1	IL005	Applied Imagination	12/15	Unusual
	IL006	Challenges of Climate Change	7.5/15	Unusual
Term 2	IL016	The Science of Music	7.5/12/15	Unusual
	IL023	Genetics: Science and Society	12/15	Unusual

Statistics Modules

hide

Term	Code	Module	CATS	G100	G103
Term 1	ST220	Introduction to Mathematical Statistics	12	List B	List B
	ST222	Games, Decisions and Behaviour	12	List B	List B
	ST301	Bayesian Statistics and Decision Theory	15	List B	List B
	ST333	Applied Stochastic Processes	15	List B	List B
	ST339	Mathematical Finance	15	List A	List B
	ST407	Monte Carlo Methods	15	List B	List B
	ST411	Dynamic Stochastic Control	15	List A	List C
Term 2	ST305	Designed Experiments	15	List B	List B
	ST318	Probability Theory	15	List A	List A
	ST323	Multivariate Statistics	15	List B	List B
	ST329	Topics in Statistics	15	List B	List B
	ST332	Medical Statistics	15	List B	List B
	ST343	Topics in Data Science	15	List B	List B
	ST337	Bayesian Forecasting and Intervention	15	List B	List B
	ST416	Advanced Topics in Biostatistics	15	List B	List B

Economics Modules

The Economics 2nd and 3rd Year Handbook, which includes information on which modules will actually run during the academic year, is available from the Economics web pages.

hide

Term	Code	Module	CATS	List
Term 1	EC220	Mathematical Economics 1A	15	List B
Term 2	EC221	Mathematical Economics 1B	15	List B

Computer Science

hide

Term	Code	Module	CATS	G100	G103
Term 1	CS301	Complexity of Algorithms	15	List A	List B
	CS324	Computer Graphics	15	List B	List B
	CS325	Compiler Design	15	List B	List B
Term 2	CS341	Advanced Topics in Algorithms	15	List A	List B
	CS409	Algorithmic Game Theory	15	List A	List B

Physics

hide

Term	Code	Module	CATS	G100	G103
Term 1	PX350	Weather and the Environment	7.5	List B	List B
	PX308	Physics in Medicine	7.5	List B	List B
	PX366	Statistical Physics	7.5	List A	List B
	PX382	Quantum Physics of Atoms	7.5	List B	List B
	PX384	Electrodynamics	7.5	List A	List B
	PX390	Scientific programming	15	List A	List B
	PX392	Plasma Electrodynamics	7.5	List A	List B
	PX397	Galaxies	7.5	List B	List B
	PX420	Solar Magnetohydrodynamics	7.5	List A	List B
	PX425	High Performance Computing in Physics	7.5	List A	List C
	PX436	General Relativity	15	List A	List C
Term 2	PX370	Optoelectronics and Laser Physics	7.5	List B	List B
	PX387	Astro Physics	15	List B	List B
	PX389	Cosmology	7.5	List B	List B
	PX396	Nuclear Physics	7.5	List B	List B
	PX408	Relativistic Quantum Mechanics	7.5	List A	List C
	PX423	Kinetic Theory	7.5	List A	List B
	PX430	Gauge Theories for Particle Physics	7.5	List A	List C

Engineering

hide

Term	Code	Module	CATS	G100	G103
Term 2	ES3C8	Systems Modelling and Control	15	List A	List B

Warwick Business School

Students wishing to take Business Studies options should preregister using the online module registration (OMR) in year two. If students wish to take an option for which they have not preregistered in year two they should register as early as possible *directly with the Business School* since occasionally the numbers of places on these modules s restricted. More information is available from Room E0.23, WBS. If you start a Business Studies module and then give it up, you *must* formally deregister with the module secretary. Information for all WBS modules can be found here.

hide

Term	Code	Module	CATS	List
Term 1	IB253	Principles of Finance I	12 or 15	List B
	IB313	Business Studies I	15	List B
	IB349	Operational Research for Strategic Planning	12	List B
Term 2	IB211	Simulation	12 or 15	List B
	IB217	Starting a Business	6	List B
	IB254	Principles of Finance II	12 or 15	List B
	IB314	Business Studies II	15	List B
	IB320	Simulation	12	List B
	IB352	Mathematical Programming III	15	List B
	IB3A7	The Practice of Operational Research	12	List B

Philosophy

hide

Term	Code	Module	CATS	G100	G103
Term 1	PH210	Logic II: Metatheory	15	List B	List B

Centre for Education Studies

Note: we advise students to take this module in their second year rather than third since it involves teaching practice over the Easter vacation which may interfere with revision for final year modules examined immediately after that vacation.

hide

Term	Code	Module	CATS	List
Term 2	IE3E1	Introduction to Secondary School Teaching	24	List B

Languages

The Language Centre offers academic modules in Arabic, Chinese, French, German, Japanese, Russian and Spanish at a wide range of levels. These modules are available for exam credit as unusual options to mathematicians in all years. Pick up a leaflet listing the modules from the Language Centre, on the ground floor of the Humanities Building by the Central Library. Full descriptions are available on request. Note that you may only take one language module (whether as an Unusual Option or from List B) for credit in each year. Language modules are available as whole year modules, or smaller term long modules. Both options are available to maths students. These modules may carry 24 (12) or 30 (15) CATS and that is the credit you get. But, where a language module is offered at a choice of 24 (12) or 30 (15) CATS, you MUST choose the 24 (12) CATS version.

Note 3rd and 4th year students cannot take beginners level (level 1) Language modules.

There is also an extensive and very popular programme of lifelong learning language classes provided by the centre to the local community, with discounted fees for Warwick students. Enrolment is from 9am on Wednesday of week 1. These classes do not count as credit towards your degree.

The Language Centre also offers audiovisual and computer self-access facilities, with appropriate material for individual study at various levels in Arabic, Chinese, Dutch, English, French, German, Greek, Italian, Portuguese, Russian and Spanish. (This kind of study may improve your mind, but it does not count for exam credit.)

A full module listing with descriptions is available on the Language Centre web pages.

Important note for students who pre-register for Language Centre modules

It is essential that you confirm your module pre-registration by coming to the Language Centre as soon as you can during week one of the new academic year. If you do not confirm your registration, your place on the module cannot be guaranteed. If you decide, during the summer, NOT to study a language module and to change your registration details, please have the courtesy to inform the Language Centre of the amendment.

Information on modules can be found at

http://www2.warwick.ac.uk/fac/arts/languagecentre/academic/

Objectives

After completing the third year of the BSc degree or MMath degree the students will have

- covered advanced material in mathematics, and studied some of it in depth
- achieved a level of mathematical maturity which has progressed from the skills expected in school mathematics to the understanding of abstract ideas and their applications
- developed
  1. investigative and analytical skills,
  2. the ability to formulate and solve concrete and abstract problems in a precise way, and
  3. the ability to present precise logical arguments
- been given the opportunity to develop other interests by taking options outside the Mathematics Department in all the years of their degree course.

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

IE420 Problem Solving

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ie420)
Lecturer: David Wood

Term: term 2

Status for Mathematics students: List B for second and third years

Commitment: 10 two hour sessions, 10 one hour problem solving seminars (assessed)

Assessment: 10% from weekley seminars, 40% from assignment, 50% two hour exam in June.

Prerequisites: None

Introduction
This module gives you the opportunity to engage in mathematical problem solving and to develop problem solving skills through reflecting on a set of heuristics. You will work both individually and in groups on mathematical problems, drawing out the strategies you use and comparing them with other approaches.

General aims
This module will enable you to develop your problem solving skills; use explicit strategies for beginning, working on and reflecting on mathematical problems; draw together mathematical and reasoning techniques to explore open ended problems; use and develop schema of heuristics for problem solving.

This module provides an underpinning for subsequent mathematical modules. It should provide you with the confidence to tackle unfamiliar problems, think through solutions and present rigorous and convincing arguments for your conjectures. While only small amounts of mathematical content will be used in this course which will extend directly into other courses, the skills developed should have wide ranging applicability.

Intended Outcomes

Learning objectives
The intended outcomes are that by the end of the module you should be able to:

- Use an explicit problem solving scheme to control your approach to mathematical problems
- Explain the role played by different phases of problem solving
- Critically evaluate your own problem solving practice

Organisation
The module runs in term 2, weeks 1-10

Main Lecture: Friday 3-5pm R0.3/4

Problem Solving Seminar (assessed): Thursday 14:00-15:00 F1.10 (beginning week TWO)

Assessment Details

1. A flat 10% given for 'serious attempts' at problems during the course. Each week, you will be assigned a problem for the seminar. At then end of the seminar, you should present a 'rubric' of your work on that problem so far. If you submit at least 7 rubrics, deemed to be 'serious attempts', you will get 10%.
2. One problem-solving assignment (40%) (deemed to be the equivalent of 2000 words) due by noon on Friday 14th March 2014. Sumbmission will either be paper copies to the Mathematics department Undergraduate Office or electronic upload, to be confirmed nearer the deadline.
3. A 2 hour examination in Summer Term 2014 (50%).

Additional Resources (Moodle page)

MA3E7 Problem Solving

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3e7)

Lecturer: Dave Wood and Mark Cummings

Term(s): Term 2

Status for Mathematics students: List B for third years. If numbers permit second and fourth years may take this module as an unusual option, but confirmation will only be given at the start of Term 2.

Commitment: 10 two hour and10 one hour seminars (including some assessed problem solving)

Assessment: 10% from weekley seminars, 40% from assignment, 50% two hour exam in June

Prerequisites: None

Introduction
This module gives you the opportunity to engage in mathematical problem solving and to develop problem solving skills through reflecting on a set of heuristics. You will work both individually and in groups on mathematical problems, drawing out the strategies you use and comparing them with other approaches.

General aims
This module will enable you to develop your problem solving skills; use explicit strategies for beginning, working on and reflecting on mathematical problems; draw together mathematical and reasoning techniques to explore open ended problems; use and develop schema of heuristics for problem solving.

This module provides an underpinning for subsequent mathematical modules. It should provide you with the confidence to tackle unfamiliar problems, think through solutions and present rigorous and convincing arguments for your conjectures. While only small amounts of mathematical content will be used in this course which will extend directly into other courses, the skills developed should have wide ranging applicability.

Intended Outcomes

Learning objectives

The intended outcomes are that by the end of the module you should be able to:

- Use an explicit problem solving scheme to control your approach to mathematical problems
- Explain the role played by different phases of problem solving
- Critically evaluate your own problem solving practice

Organisation

The module runs in term 2, weeks 1-10

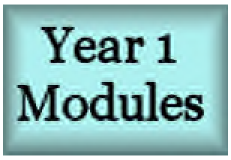
Thursday 14:00-15:00 OC0.04 (new teaching and learning building)
Friday 15:00-17:00 OC0.04

Most weeks the Thursday slot will be used for the weekly (assessed) problem session, but this will not be the case every week. You are expected to attend all three timetabled hours.

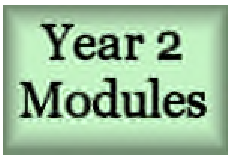
Assessment Details

1. A flat 10% given for 'serious attempts' at problems during the course. Each week, you will be assigned a problem for the seminar. At then end of the seminar, you should present a 'rubric' of your work on that problem so far. If you submit at least 7 rubrics, deemed to be 'serious attempts', you will get 10%.
2. One problem-solving assignment (40%) (deemed to be the equivalent of 2000 words) due by noon on Monday 20th March 2017 by electronic upload (pdf).
3. A 2 hour examination in Summer Term 2017 (50%).

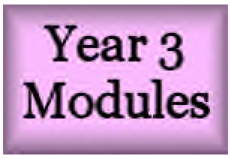
Additional Resources (Moodle page)



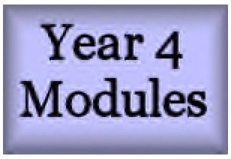
Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

Exam Information

Past Exams

Core module averages

MA3E7 2017 Seminars

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3e7/2017seminars)
Correct as of end of term 2 (i.e. post final problem session)

X problem for that week passed

<blank> no problem submitted/didn't pass

AA authorsied absence

100 you have at least 7 problems and will get 100% for this component

0 you do not have at least 7 problems and will get 0% for this component

You are not signed in

This page is designed to display information specific to you, so you need to sign in first.

MA3J2 Combinatorics II

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3j2)
Lecturer: Keith Ball

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 Lectures

Assessment: Summer exam (100%)

Prerequisites: MA241 Combinatorics

Leads To: MA4J3 Graph Theory

Content:
Some or all of the following topics:

• Partially order sets: Dilworth's theorem, Sperner's theorem, the LYM inequality.
• Symmetric functions, Young Tableaux.
• Designs and codes: Latin squares, finite projective planes, error-correcting codes
• Colouring: the chromatic polynomial,
• Geometric combinatorics: Caratheodory's Theorem, Helly's Theorem, Radon's Theorem
• Probabilistic method: the existence of graphs with karge girth and high chromatic number, use of concentration bounds
• Matroid theory: basic concepts, Rado's Theorem
• Regularity method: regularity lemma without a proof, the existence of 3-APs in dense subsets of integers

Aims:
To give the students an opportunity to learn some of the more advanced combinatorial methods, and to see combinatorics in a broader context of mathematics.

Objectives:
By the end of the module the student should be able to:
• state and prove particular results presented in the module
• adapt the presented methods to other combinatorial settings
• apply simple probabilistic and algebraic arguments to combinatorial problems
• use presented discrete abstractions of geometric and linear algebra concepts
• derive approximate results using the regularity method

Books:
R. Diestel: Graph Theory, Springer, 4th edition, 2012.
R. Stanley: Algebraic Combinatorics: Walks, Trees, Tableaux and More, Springer, 2013.

Additional Resources

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

MA3J3 Bifurcations, Catastrophes and Symmetry

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3j3)
Lecturer: Dr. David Wood

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 Lectures

Assessment: 100% exam

Prerequisites: MA133 Differential Equations, MA249 Algebra II, MA225 Differentiation

Leads to:

Content: This module investigates how solutions to systems of ODEs (in particular) change as parameters are smoothly varied resulting in smooth changes to steady states (bifurcations), sudden changes (catastrophes) and how inherent symmetry in the system can also be exploited. The module will be application driven with suitable reference to the historical significance of the material in relation to the Mathematics Institute (chiefly through the work of Christopher Zeeman and later Ian Stewart). It will be most suitable for third year BSc. students with an interest in modelling and applications of mathematics to the real world relying only on core modules from previous years as prerequisites and concentrating more on the application of theories rather than rigorous proof.

Indicative content (precise details and order still being finalised):

1. Typical one-parameter bifurcations: transcritical, saddle-node, pitchfork bifurcations, Bogdanov-Takens, Hopf bifurcations leading to periodic solutions. Structural stability.
2. Motivating examples from catastrophe and equivariant bifurcation theories, for example Zeeman Catastrophe Machine, ship dynamics, deformations of an elastic cube, D_4-invariant functional.
3. Germs, equivalence of germs, unfoldings. The cusp catastrophe, examples including Spruce-Budworm, speciation, stock market, caustics. Thom's 7

Elementary Catastrophes (largely through exposition rather than proof). Some discussion on the historical controversies.
4. Steady-State Bifurcations in symmetric systems, equivariance, Equivariant Branching Lemma, linear stability and applications including coupled cell networks and speciation.
5. Time Periocicity and Spatio-Temporal Symmetry: Animal gaits, characterization of possible spatio-temporal symmetries, rings of cells, coupled cell networks, H/K Theorem, Equivariant Hopf Theorem.

Further topics from (if time and interest):

Euclidean Equivariant systems (example of liquid crystals), bifurcation from group orbits (Taylor Couette), heteroclinic cycles, symmetric chaos, Reaction-Diffusion equations, networks of cells (groupoid formalism).

Aims: Understand how steady states can be dramatically affected by smoothly changing one or more parameters, how these ideas can be applied to real world applications and appreciate this work in the historical context of the department.

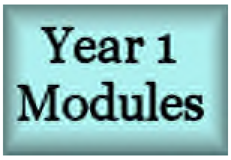
Objectives:

Books:

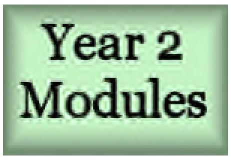
There is no one text book for this module, but the following may be useful references:

- Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields, Guckenheimer/Holmes 1983
- Catastrophe Theory and its Applications, Poston and Stewart, 1978
- The Symmetry Perspective, Golubitsky and Stewart, 2002
- Singularities and Groups in Bifurcation Theory Vol 2, Golubitsky/Stewart/Schaeffer 1988
- Pattern Formation, an introduction to methods, Hoyle 2006.

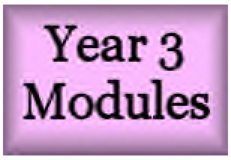
Additional Resources



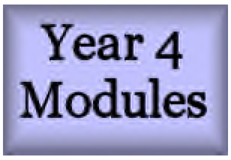
Year 1 regs and modules
G100 G103 GL11 G1NC



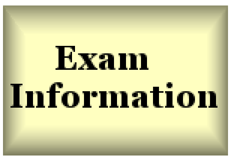
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA3J4 Mathematical modelling with PDE

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3j4)

Lecturer: Marie-Therese Wolfram

Term(s): Term 1

Status for Mathematics students:

Commitment: 30 Lectures

Assessment: Assessed example sheets (15%), Summer exam (85%).

Prerequisites: MA250 PDE

Leads To: The students will be given a general overview on the derivation and use of partial differential equations modeling real world applications. By the end of the course they should have aquired knowledge about the physical interpretation of PDE models and how the learned techniques can be applied to similar problems.

Content:

1. Mathematical modelling
   - Math. modelling in physics, chemistry, biology, medicine, economy, finance, art, transport, architecture, sports
   - Qualitative/quantitative models, discrete/continuum models
   - Scaling, dimensionless variables, sensitivity analysis
   - Examples: projectile motion, chemical reactions
2. Diffusion and drift
   - Microscopic derivation
   - Continuity equation and Fick's law
   - Heat equation: scaling, properties of solutions
   - Reaction diffusion systems: Turing instabilities
   - Fokker-Planck equation
3. Transport and flows
   - Conservation of mass, momentum and energy
   - Euler and Navier-Stokes equations
4. From Newton to Boltzmann
   - Newton's laws of motion
   - Vlasov and Boltzmann equation
   - Traffic flow models

Aims: The module focuses on mathematical modelling with the help of PDEs and the general concepts and techniques behind it. It gives an introduction to PDE modelling in general and provides the neccesary basics.

Objectives: By the end of the module students should be able to:

- Understand the nature of micro- and macroscopic models.
- Formulate models in dimensionless quantities
- Have an overview of well known PDE models in physics and continuum mechanics
- Calculate solutions for simple PDE models
- Use and adapt Matlab programs provided during the module

Books:

- J. David Logan, Applied Mathematics: A Contemporary Approach
- C.C.Lin, A. Segel, Mathematics Applied to Deterministic Problems in the Natural Sciences, 1988
- A. Aw, A. Klar, Rascle and T Materne, Derivation of continuum traffic flow models from microscopic follow the leader models, SIAM Appl Math., 2002
- B. Perthame, Transport equations in biology, Birkhäuser, 2007
- R. Illner, Mathematical Modelling: A Case Study Approach, SIAM, 2005
- C. Eck, H. Garcke, P. Knaber, Mathematische Modellierung, Springer, 2008
- L. Pareschi and G. Toscani, Interacting Multiagent Systems, Oxford University Press, 2013

Additional Resources

CS341 Advanced Topics in Alogrithms

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/cs341)

Academic Aims

To introduce students to new techniques, methods and results from the rapidly-developing field of algorithms. Typical topics include randomised algorithms, graph algorithms, matrix algorithms and counting algorithms. The module will be research-led, so exact topics will vary from year to year.

Learning Outcomes

Students will be able to understand a variety of advanced algorithmic techniques, use recently-developed algorithmic techniques to solve problems, and understand the state of the art in some areas of algorithmic research, including new developments and open problems.

Content

- Basic parallel computation models: circuits, comparison networks. Parallel merging and sorting by comparison networks.
- Advanced parallel computation models: PRAM, BSP.
- Fundamental parallel algorithms: total exchange, broadcast/combine, prefix sums, butterfly, grid.
- Further parallel algorithms: list and tree contraction, sorting, convex hull
- Parallel matrix algorithms: matrix-vector multiplication, matrix multiplication, triangular system solution, Gaussian elimination.
- Parallel graph algorithms: algebraic paths, all-pairs shortest paths, minimum spanning tree.

Content in previous years.

- Sorting, selection, etc.
- Search trees, skip lists.
- Cuts, flows, approximation algorithms for graph problems.
- Online algorithms.

CS349 Principles of Programming Languages

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/cs349)

Academic Aims

The module introduces students to fundamental concepts underpinning programming languages and to reasoning about program behaviour.

Learning Outcomes

By the end of the module the student should be able to:

- Understand a variety of concepts underpinning modern programming languages.
- Distinguish type disciplines in various programming languages.
- Use formal semantics to reason aboutprogram behaviour.
- Implement program interpreters and type inference algorithms.

Content

Scope and binding, untyped programming, type systems, type inference, evaluation relations, higher-order types, references, control operators, subtyping, recursive types, polymorphism.

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules
Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules
Year 3 regs and modules
G100 G103

Year 4 Modules
Year 4 regs and modules
G103

Exam Information
Past Exams
Core module averages

CS409 Algorithmic Game Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/cs409)

Academic Aims

To familiarise students with formal methods of strategic interaction, as studied in game theory. The focus of the module is on algorithmic and computational complexity aspects of game-theoretic models. One of the aims will be to give a flavour of current research and most recent advances in the field of algorithmic game theory.

Learning Outcomes

On successful completion of the module students should be able to:

- Understand the fundamental concepts of non-co-operative and co-operative game theory, in particular standard game models and solution concepts.
- Understand a variety of advanced algorithmic techniques and complexity results for computing game-theoretic solution concepts (equilibria).
- Apply solution concepts, algorithms, and complexity results to unseen games that are variants of known examples.
- Understand the state of the art in some areas of algorithmic research, including new developments and open problems.

Content

- Game models: Strategic form, extensive form, games of incomplete information (eg auctions), succinct representations, market equilibria, network games, co-operative games.
- Solution concepts: Nash equilibria, subgame perfection, correlated equilibria, Bayesian equilibria, core and Shapley value.
- Quality of equilibria: Price of anarchy, price of stability, fairness.
- Finding equilibria: Linear programming algorithms, Lemke-Howson algorithm, finding all equilibria.
- Complexity of results: Efficient algorithms, NP-completeness of decision problems relating to set of equilibria, PPAD-completeness.

Some parts of the module will be research-led, so some topics will vary from year to year.

Year 1 Modules
Year 1 regs and modules
G100 G103 GL11 G1NC

MA3H7 Control Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h7)
Lecturer: Christoph Ortner

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one hour lectures

Assessment: Three hour examination

Prerequisites: MA106 Linear Algebra, MA133 Differential Equations [Recommended: ST112 Probability B]

Leads to:

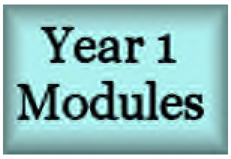
Content:
Will include the study of controllability, stabilization, observability, filtering and optimal control. Furthermore connections between these concepts will also be studied. Both linear and nonlinear systems will be considered. The module will comprise six chapters. The necessary background material in linear algebra, differential equations and probability will be developed as part of the course.
1. Introduction to Key Concepts.
2. Background Material.
3. Controllability.
4. Stabilization.
5. Observability and Filtering.
6. Optimal Control.

Aims:
The aim of the module is to show how, as a result of extensive interests of mathematicians, control theory has developed from being a theoretical basis for control engineering into a versatile and active branch of applied mathematics.

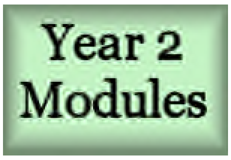
Objectives:
By the end of the module the student should be able to:
Explain and exploit role of controllability matrix in linear control systems.
Explain and exploit stabilization for linear control systems.
Derive and anlayze the Kalman filter.
Understand linear ODEs and stability theory.
Understand and manipulate Gaussian probability distributions.
Understand basic variational calculus for constrained minimization in Hilbert space.

Books:
E. D. Sontag, *Mathematical Control Theory: deterministic finite dimensional systems*, Texts in Applied Mathematics No 6, Springer Verlag, 1990.
J. Zabczyk, *Mathematical Control Theory: An Introduction*, Birkhauser, 1992.

Additional Resources



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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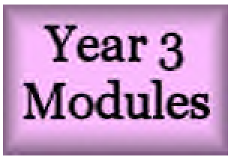
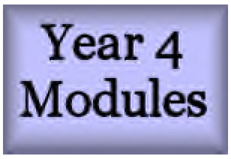
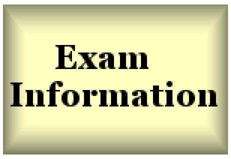


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

PH341 Modal Logic

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ph341)

TIMING & CATS

This module is not running in 2017-18.

MODULE DESCRIPTION

Modal operators are expressions such as it is necessary/possible that, in the future/past, it is obligatory/ permissible that, it is known/believed that, it is provable that, it is true after performing computational operation α that which when prefixed to a declarative sentence can be understood to modify the way in which it is true. Modal logic – i.e. the study of formal systems for reasoning about such operators – finds far reaching applications in philosophy, computer science, and mathematical logic.

We will begin studying axiom and tableau proof systems for some common propositional and first-order modal logics. We next consider a semantic theory for these systems in the form of Kripke (or possible world) models relative to which we will prove the soundness and completeness of the logics in question. Here are some topics we will touch on along the way: rigid designation and the de re/de dicto distinction (philosophy of language), possibilist versus actualist quantification (metaphysics), logical omniscience and bounded rationality (epistemology), intuitionism, formal versus informal provability and Gödel's Incompleteness Theorems (mathematical logic), using modal logic to reason about distributed systems and program correctness (computer science).

LEARNING OUTCOMES OR AIMS

By the end of the module the student should be able to: 1) demonstrate knowledge of formal systems of modal logic (proof theory and semantics); 2) understand the relationships between these formal systems and questions, e.g., about the nature of modality, identity, or conditionals; 3) use and define concepts with precision, both within formal and discursive context.

CONTACT TIME

In this module students must attend 3 hours of lectures and a one hour seminar per week attended by all students.

Lectures for 2016-17

TBC

ASSESSMENT METHODS

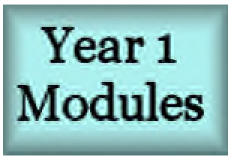
This module is formally assessed in the following way:

- Assessed exercises (15% of module)
- 2-hour examination (85% of module)

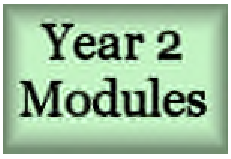
Course materials

From October 2016 course materials will be available on Moodle. Simply sign in and select the module from your Moodle home page.

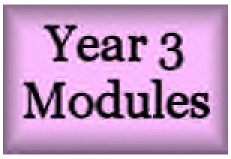
Please note you must be regisitered for the module on eMR in order to access the relevant page.



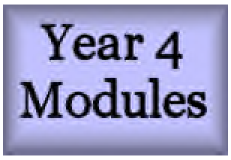
Year 1 regs and modules
G100 G103 GL11 G1NC



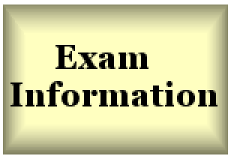
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

PH342 Philosophy of Mathematics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ph342)

Timing & CATS

This module is not running in 2017-18.

Module Description

This module will be a survey of philosophy of mathematics. We will begin by focusing on classical (Plato and Aristotle) and modern (Descartes, Kant, and Mill) sources. We will then turn to the major foundational schools of the early 20th century: logicism (Frege and Russell), intuitionism (Brouwer and Heyting) and formalism (Hilbert). We'll next consider the early development of set theory and the major limitative results of the 1930s (e.g. Gödel's Incompleteness Theorems) and inquire into their significance with respect to mathematical knowledge, provability, truth, and ontology. Finally we will survey several recent philosophical proposals about the nature of mathematics (structuralism, nominalism, fictionalism).

Learning Outcomes or Aims

By the end of the module the student should be able to: 1) demonstrate knowledge of some of the central topics in the philosophy of mathematics, and of the history; 2) understand the significance questions in the philosophy of mathematics have to wider issues in philosophy and the foundations of mathematics; 3) articulate their own view of the relative merits of different theories and engage critically with the arguments put forward in support of them.

Contact Time

In this module students must attend 2 hours of lectures and a one hour seminar per week

Lectures for 2014-15

- **Mondays 12pm-2pm F1.10**
- **Mondays 6pm-7pm MS.04**

ASSESSMENT METHODS

This module is formally assessed in the following way:

- 100% examined (2 hour exam)
- 100% assessed (2500 word essay)

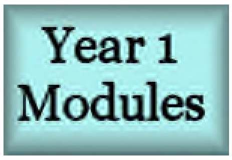
Course materials from

- 2014/15

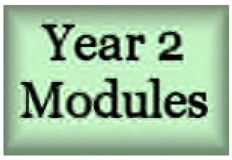
Previous years

Please be aware that these materials may not be relevant to the current version of this module; they are intended primarily for students who took the module in other years.

- 2012/13
- 2010/11



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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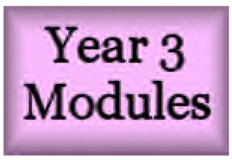
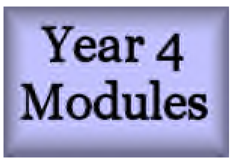


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

PH345 Philosophy of Computation

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ph345)

Timing & CATS

This module is running in the Spring Term and is worth 15 CATS.

Module Description

The purpose of this module is to provide a non-technical introduction to theoretical computer science and philosophical issues about computation. Among the questions we will address are the following: is it possible to provide a mathematically precise analysis of the intuitive notion of a computable function? do there exist functions which are non-computable even in principle? what does it mean to say that one computational problem (e.g. determining if a number is prime) is harder or more complex then another (e.g. determining if a number is even)? what does it mean to say that sequence of natural numbers is random or incompressible by a computer? is the mind a computer and can mathematical results (e.g. Gödel's Incompleteness Theorems) be used to confirm or disconfirm such a possibility? what does it mean for a physical system to realize a computer? do results from contemporary physics bear on this?

Learning Outcomes or Aims

By the end of the module the student should be able to: 1) demonstrate knowledge of topics about computation; 2) understand the significance these systems to problems in philosophy.

Contact Time

In this module students must attend 2 hours of lectures and 1 hour of seminars per week.

Lectures for 2017-18

- **Monday 12pm to 2pm in S0.19**
- **Monday 6pm to 7pm in MS.04**

There will be no lectures during reading week (week 6)

Seminars for 2017-18

Seminars for this course start in week 2.

There will be no seminars during reading week (week 6)

Please sign up for a seminar group using Tabula.

Assessment Methods

This module will be assessed in the following way:

- 15% assessed and 85% examined (2 hour exam)

The assessed component consists in fortnightly exercise sets, which are to be handed in directly to the module leader at the relevant lectures.

Background Reading & Textbooks

David Harel, Algorithmics: The Spirit of Computing, 3rd edition, Addison-Wesley 2004.

Michael Sipser, Introduction to the theory of computation, 2nd edition, Thomson, 2006.

Course Materials

From October 2016 course materials will be available on Moodle. Simply sign in and select the module from your Moodle home page.

PX408 Relativistic Quantum Mechanics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px408)

Lecturer: Tim Gershon

Weighting: 7.5 CATS

The module sets up the relativistic analogues of the Schrödinger equation and analyses their consequences. Constructing the equations is not trivial - knowing the form of the ordinary Schrödinger equations turns out not to be much help. The correct equation for the electron, due to Dirac, predicts antiparticles, spin and other surprising phenomena. One is the 'Klein Paradox': When a beam of particles is incident on a high potential barrier, more particles can be 'reflected' than are actually incident on the barrier.

Aims:

This module should start from the premise that quantum mechanics and relativity need to be mutually consistent. The Klein Gordon and Dirac equations should be derived as relativistic generalisations of Schrödinger and Pauli equations respectively. The Dirac equation should be analysed in depth and its successes and limitations will be stressed.

Objectives:

At the end of this module you should:

- have an appreciation of the general nature of Relativistic Quantum Mechanics.
- have an understanding of the Dirac equation, its significance and its transformation properties
- be able to explain how some physical phenomena including spin, the gyromagnetic ratio of the electron and the fine structure of the hydrogen atom can be accounted for using relativistic quantum mechanics

Syllabus:

Introductory Remarks
Revision of relativity, electromagnetism and quantum mechanics; problems with the non-relativistic Schrödinger equation; unnaturalness of spin in NRQM and the Pauli Hamiltonian; phenomenology of relativistic quantum mechanics, such as pair production
Klein Gordon Equation
Derivation of the Klein-Gordon equation; continuity equation and the Klein-Gordon current; problems with the interpretation of the Klein-Gordon Equation
The Dirac Equation
Deriviation of the Dirac equation; the unavoidable emergence of the quantum phenomena of spin; gamma matrix algebra and equivalence transformations
Solutions of the Dirac Equation
The helicity operator and spin; normalisation of Dirac spinors; Lorentz transformations of Dirac spinors; interpretation of negative energy states

Applications of Relativistic Quantum Mechanics
The gyromagnetic ratio of the electron; non-relativistic limit of the Dirac equation; fine structure of the hydrogen atom

Commitment: 15 Lectures

Assessment: 1.5 hour examination

The module has a website.

Recommended Text: The course closely follows
R.Feynman, Quantum Electrodynamics, Perseus Books 1998

Leads from: PX109 Relativity; PX262 Quantum Mechanics and its Applications

Leads to: PX430 Gauge Theories of Particle Physics;

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

PX420 Solar Magnetohydrodynamics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px420)

Lecturer: Valery Nakariakov

Weighting: 7.5 CATS

Our knowledge of what is happening in the sun is increasing rapidly, largely as a result of space-based instrumentation. The challenge now is to understand it. The basic process is simple: Heat moves outwards from its source at the centre (nuclear fusion). However, on its way out, this energy drives many processes on many different length scales many of which are not at all well understood. For example, there is still no convincing theory of how the sun's magnetic field is generated and how the atmosphere is heated.

This module starts by stating the basic properties of the sun as deduced from observation and general physical principles, and introduces a hydrodynamic model of the sun. This treats the solar matter as a fluid. There are the usual gravitational and pressure gradient forces governing the fluid motion but, because the constituent particles of the fluid are charged, there are also electromagnetic forces. As a result, we need to worry about Maxwell's equations as well as Newton's laws. The module then discusses applications of this theory, called magnetohydrodynamics, to model and understand phenomena like sunspots, coronal loops, prominences, solar flares, coronal mass ejections and space weather.

Aims:
To review the basic physics underlying the structure and the dynamics of the sun, to provide a background in the description of physical processes in the Sun in terms of magnetohydrodynamics and to show the results of recent observations.

Objectives:
At the end of this module you should:

- Know the structure of the Sun and the main features and phenomena observed on the solar surface and in the solar atmosphere
- Understand the basic physical processes at work in the sun
- Be able to describe the basic dynamic processes operating in the Sun, in terms of MHD

Syllabus:

1. An outline of observational properties ranging from the solar interior ot the Sun's outer atmosphere
2. Theoretical aspects of solar magnetohydrodynamics (MHD)
3. Magnetic equilibria. Stratification. Force-free magnetic fields. Magnetic arcades, prominences, suspots, intense flux tubes.
4. MHD Waves. Helioseismology.
5. Solar flares. Heating of the solar corona. Coronal mass ejections and space weather.

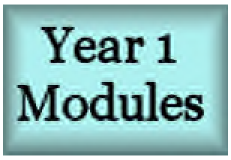
Commitment: 15 Lectures

Assessment: 1.5 hour examination

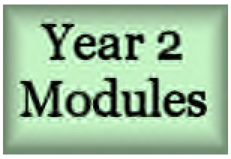
The module has a website.

Recommended Texts:
ER Priest, *Solar Magnetohydrodynamics*, Dordrecht ;
L Golub and JM Pasachoff,*Nearest Star: The Surprising Science of Our Sun*, Harvard Univ. press

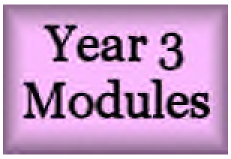
Leads from: PX264 Physics of Fluids and PX392 Plasma Electrodynamics



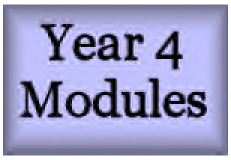
Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

Exam Information

Past Exams

Core module averages

PX421 Relativity and Electrodynamics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px421)

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Year 1 Modules

Year 1 regs and modules

G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules

G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules

G100 G103

Year 4 Modules

Year 4 regs and modules

G103

Exam Information

Past Exams

Core module averages

PX423 Kinetic Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px423)

This page has no content yet.

Year 1 Modules

Year 1 regs and modules

G100 G103 GL11 G1NC

PX425 High Performance Computing in Physics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px425)

Lecturer: Nick Hine

Weighting: 7.5 CATS

The aim of this module is to complete your training in the use of computers by exploring the use of super-computers to solve super problems. The module teaches how to write scalable, portable programs for parallel computer systems and explore how large-scale physics problems are tackled. This module is 100% continuously assessed (there is no examination).

Aims:
To explain the methods used in computer simulations and data analysis on high performance computers, for research in all fields of computational physics and other sciences.

Objectives:
At the end of this module you should be able to:

- Identify and correct common inefficiencies in both serial scientific computer codes
- Choose an appropriate programming paradigm for a particular problem or hardware architecture
- Write a parallel program using shared-memory or message passing constructs in a physics context
- Write a simple GPU accelerated program.
- Identify sources of performance bottlenecks in parallel computer programs and understand how these relate to the computer architecture
- Use batch systems to access parallel computing hardware and to validate the correctness of a parallel computer program vs equivalent serial software

Syllabus:

Programming for efficiency. Modern cache architectures and CPU pipelining. Avoiding expensive and repeated operations. Compiler optimisation flags. Profiling with gprof.

Introduction to parallel computing. Modern HPC hardware and parallelisation strategies. Applications in Physics, super problems need super-computers.

Shared memory programming. The OpenMP standard. Parallelisation using compiler directives. Threading and variable types. Loop and sections constructs. Program correctness and reproducibility. Scheduling and false sharing as factors influencing performance.

Distributed memory programming. The MPI standard for message passing. Point-to-point and collective communication. Synchronous vs asynchronous communication. MPI communicators and topologies.

GPU programming. CUDA vs OpenCL. Kernels and host-device communication. Shared and constant memory, synchronicity and performance. GPU coding restrictions.

Limitations to parallel performance. Strong vs weak scaling. Amdahl's law. Network contention in modern many-core architectures. Mixed mode OpenMP+MPI programming.

Commitment: 15 Lectures + 5 Laboratory Sessions

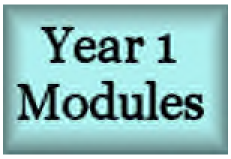
Assessment: Assignments (100%)

Recommended Texts: R Chandra et. al,. *Parallel Programming in OpenMP* , Morgan Kaufmann,
P Pacheco, *Parallel Programming with MPI* Morgan Kaufmann
M Quinn, *Parallel Programming in C with MPI and OpenMP* McGraw-Hill
D Kirk and W Hwu, *Programming Massively Parallel Processors* Elsevier

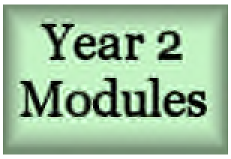
Module Homepage

This module has its own website where lecture notes and other resources are available.

Leads from: PX390 Scientific Computing A good working knowledge of a scientific programming language preferably C is essential.



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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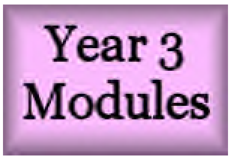
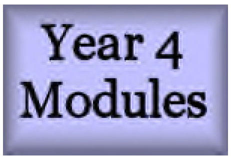
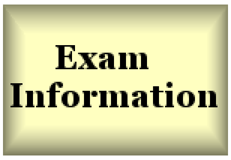


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

PX429 Scattering and Spectroscopy

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px429)

Lecturer: Gareth Alexander

Weighting: 15 CATS

Einstein's general theory of relativity is the basis for our understanding of black holes and the Universe on its largest scales. In general relativity the Newtonian concept of a gravitational force is abolished, to be replaced by a new notion, that of the curvature of space-time. This leads in turn to predictions of phenomena such as the bending of light and gravitational time dilation that are well tested, and others, such as gravitational waves, which are only now coming into the regime of direct detection.

The module starts with a recap of Special Relativity, emphasizing its geometrical significance. The formalism of curved coordinate systems is then developed. Einstein's equivalence principle is used to link the two to arrive at the field equations of GR. The remainder of the module looks at the application of general relativity to stellar collapse, neutron stars and black-holes, gravitational waves, including their detection, and finally to cosmology where the origin of the "cosmological constant" -- nowadays called "dark energy" - becomes apparent.

Aims:

To present the theory of General Relativity and its applications in modern astronomy, and to give an understanding of black-holes.

Objectives:
At the end of this module you should:

- understand the metric nature of special and general relativity, how the metric determines the motion of particles
- be able to undertake elementary calculations involving the Schwarzschild metric
- be able to describe the key features of black-holes
- be able to demonstrate knowledge of current attempts to detect gravitational waves

Syllabus:

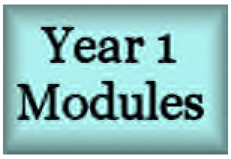
- The geometry of space-time and the invariant “interval” in special relativity; the 4-vector formulation of special relativity; the metric of special relativity
- The equivalence principle and local inertial frames; the motivation for considering curved space-time; vectors and tensors in curved coordinate systems
- Geodesics: how the metric determines equations of motion; motion in almost-flat space-time: the Newtonian limit
- The curvature and stress-energy tensors; how the metric is determined: Einstein's field equations
- The Schwarzschild metric; observable consequences; black-holes; stability of orbits; extraction of energy
- Gravitational radiation and its detection; cosmology: the Robertson-Walker metric

Commitment: 25 Lectures (and 5 problems classes)

Assessment: 2 hour examination

The module has a website.

Recommended Texts: BF Schutz *A first course in general relativity*, Cambridge University Press,
M.P Hobson, G. Efstathiou, A.N. Lasenby, *General Relativity -- An Introduction for Physicists*, CUP.



Year 1 regs and modules
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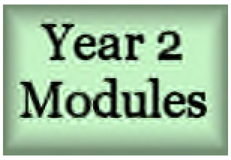

Year 2 regs and modules
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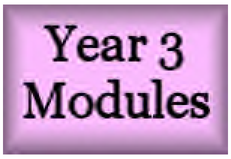
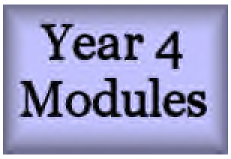


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

PX430 Gauge Theories for Particle Physics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/px430)

Lecturer: Tim Gershon

Weighting: 7.5 CATS

The electromagnetic field is a gauge field. Gauge changes to the vector potential ($A^\mu \rightarrow A^\mu - \partial^\mu \Phi$ with Φ an arbitrary function of postion and time) , combined with multiplication of the wavefunction of particles with charge *q* by the phase factor, $e^{iq\Phi}$, leave all physical properties unchanged. This is called a gauge symmetry.

In particle physics, this idea is generalized to (space- and time-dependent) unitary matrix-valued fields multiplying spinor wavefunctions and fields. This generalization of the theory of an electron in an electromagnetic field is the basis for current theories of elementary particles. The module starts with the theory of the electron in the electromagnetic field making the gauge symmetry explicit. It then discusses the gauge symmetries appropriate for the various theories and approximate theories used to describe other elementary particles and their interactions with their corresponding gauge fields.

Aims:
To follow from *Relativistic Quantum Mechanics* (which is a pre-requisite), to develop ideas of gauge theories and apply these to the field of particle physics. To study, in particular, the theory underpinning the Standard Model of Particle Physics and to highlight the symmetry properties of the theory. Quantum electrodynamics (QED) should be considered in some detail, and its success illustrated by comparison with experiments.

Objectives:
At the end of this module you should:

- have an appreciation of the theoretical framework of the Standard Model
- understand the symmetry properties associated with gauge invariance
- be able to calculate amplitudes for simple QED processes
- be able to discuss qualitatively properties of the strong and weak interactions

Syllabus:

1. Introduction and revision: relativistic quantum mechanics and notation; the Klein Gordon equation; the Dirac equation and interpretation of negative energy solutions; quantum numbers and spin; revision of matrices, Hermitan, unitary, determinants
2. Group theory: definition of a group, examples of discrete groups; continuous groups, Lie groups, examples: U(1), SU(2), SU(3)
3. Gauge invariance: symmetries and conservation laws; current conservation; Noether's theorem; the gauge principle; examples: Maxwell's equations, quantum electrodynamics
4. Quantum field theories: brief outline of the deeper theory; Feynman rules and diagrams
5. Non Abelian gauge theories: SU(2) and the electroweak interaction; SU(3) and QCD; local nonAbelian gauge theory; gauge fields; self-interaction
6. Quantum electrodynamics: perturbation theory; scattering and cross sections

Commitment: 13 Lectures and 2 problem classes

Assessment: 1.5 hour examination

The module has a website.

Recommended Texts:
IJR Aitchison and AJG Hey *Gauge Theories in Particle Physics*, IoPP

Leads from: PX395 The Standard Model and PX408 Relativistic Quantum Mechanics

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ST411 Dynamic Stochastic Control

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st411)

Lecturer(s)

Dr Adam Johansen

Commitment: 3 lectures per week, 1 computer practical per week starting in week 2.

Aims: This module will provide students with the tools for advanced statistical modelling and associated estimation procedures based on computer-intensive methods known as Monte Carlo techniques.

Content: When modelling real world phenomena statisticians are often confronted with the following dilemma: should we choose a standard model that is easy to compute with or use a more realistic model that is not amenable to analytic computations such as determining means and p-values. We are faced with such choice in a vast variety of application areas, some of which we will encounter in this module. These include financial models, genetics, polymer simulation, target tracking, statistical image analysis and missing data problems. With the advent of modern computer technology we are no longer restricted to standard models as we can use simulation-based inference. Essentially we replace analytic computation with sampling of probability models and statistical estimation. In this module we discuss a variety of such methods, their advantages, disadvantages, strengths and pitfalls.

Learning Outcomes:

- Knowledge of a collection of simulation methods including Markov chain Monte Carlo (MCMC); understanding of Monte Carlo procedures.
- Ability to develop and implement an MCMC algorithm for a given probability distribution
- Ability to evaluate a stochastic simulation algorithm with respect to both its efficiency and the validity of the inference results produced by it.
- Ability to use Monte Carlo methods for scientific applications.

Desirable Background:

- A basic knowledge of the statistical programming language R or SPLUS. Coursework will be based on R.
- Probability A & B or equivalent.
- ST218/ST219 Mathematical Statistics A & B or equivalent.

Commitment: 30 hourly lectures and 9 hourly practicals. This module runs in Term 1.

Assessment: 20% by coursework (assignment 1 10%, assignment 2 10%) and 80% by exam in April.

Syllabus:

1. **Introduction and Examples:** The need for Monte Carlo Techniques; history; example applications.

2. **Basic Simulation Principles:** Rejection method; variance reduction; importance sampling.

3. **Markov chain theory:** convergence of Markov chains; detailed balance; limit theorems.

4. **Basic MCMC algorithms:** Metropolis-Hastings algorithm; Gibbs sampling.

5. **Implementational issues:** Burn In; Convergence diagnostics, Monte Carlo error.

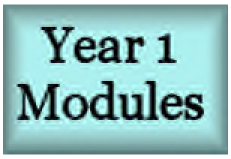
6. **More advanced algorithms:** Auxiliary variable methods; simulated and parallel tempering; simulated annealing; reversible jump MCMC.

Books:

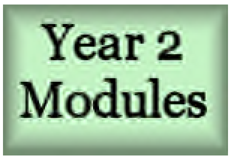
- C.P.Robert and G.Casella, Monte Carlo Statistical Methods (2nd Ed.), Springer, 2004.
- J. Voss "An introduction to Statistical Computing: A Simulation-Based Approach"
- J.S. Liu, Monte Carlo Strategies in Scientific Computing, Springer, 2001.

Deadline: Assignment 1: Thursday of week 5. Assignment 2: Thursday of week 10.

Feedback: Feedback on assignments will be returned after 2 weeks, following submission.



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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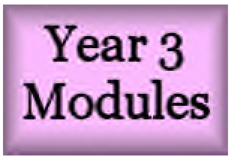
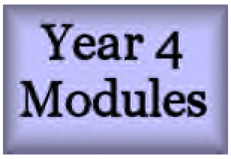
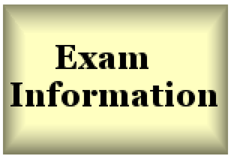


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

ST416 Advanced Topics in Biostatistics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st416)
Lecturer:

Professor David Wild

*** Please note that this module will not be running in the 2017/18 academic year. ***

Commitment: 3 lectures per week over 10 weeks. This module will run in Term 2.

Assessment: 100% by 2 hour examination

Prerequisite(s): ST111/112 Probability A and B, ST218/219 Mathematical Statistics A&B, basic computing literacy (R, Matlab,...)

Aims: This module presents the application of methods from probability, statistical theory, and stochastic processes to problems of interest to bioinformaticians and systems biologists, mainly in the area of biosequence analysis.

Objectives: It is expected that students who have taken the module will have mastered the basic set of ideas required in order to carry out further research in bioinformatics methods and algorithms, or to apply these ideas in biomedical applications.

Content:

• Single DNA sequence analysis:
- Signal modelling
- Pattern analysis

• Multiple DNA/protein sequence analysis:
- Detailed study of pairwise alignment algorithms and substitution matrices

• BLAST:
- a detailed study of the algorithm and underlying theory

• Hidden Markov models:
- Forward-Backward algorithm and parameter estimation
- Applications to protein family modelling, sequence alignment and gene finding

• Gene Expression, Microarrays and Multiple Testing:
- differential expression – one gene and multiple genes

• Evolutionary Models:
- Discrete-Time Models
- Continuous-Time Models

• Phylogenetic Tree Estimation:
- Modelling, Estimation and Hypothesis Testing

Illustrative Bibliography:
1. Statistical Methods in Bioinformatics - An Introduction, by W. J. Ewens and G. R. Grant (Springer-Verlag New York, Second Edition, 2005)
2. Biological Sequence Analysis by R. Durbin, S. Eddy, A. Krogh, G. Mitchison Cambridge University Press, 1998, ISBN: 0 521 62971 3
3. Computational Genome Analysis: An Introduction by Michael S. Waterman, Simon Tavare, Richard C. Deonier , Springer Verlag , 2005

ST417 Topics in Applied Probability

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st417)

Lecturer(s)

Dr Nikos Zygouras

Important: This module is only available to final year (4) integrated Masters students and MSc students. Please note that Topics in Applied Probability will only be taught if 5 students or more register for the module.

Lecturer(s):

Prerequisites: Being comfortable with stochastic processes, law of large numbers, central limit theorem.

Aims: This module will cover several topics chosen from modern applied probability. The topics will be selected to demonstrate how probability theory can be used to study various phenomena in the real world. Examples might include random graphs, spatial point processes, branching processes and interacting particle systems.

Commitment: 3 lectures/week. This module runs in Term 2.

Content: In the academic year 2017-2018 the topic will be " Random growth and random matrices".

The famous Kardar-Parisi-Zhang (KPZ) universality states that a large class of randomly growing models have fluctuations governed by a nonlinear stochastic partial differential equation (the KPZ equation) and fall outside the scope of the classical central limit theory. For example, the outer boundary of a colony of bacteria growing for time will exhibit fluctuations of order $t^{1/3}$, rather than $t^{1/2}$, as manifested by the central limit theorem. More surprisingly, the limiting distributions are different than gaussian and agree with distributions arising in a seemingly very different setting, that of eigenvalues of random matrices.

Both areas have witnessed remarkable progress in recent years. In random matrix theory the works of the groups of Tao-Vu and Erdos-Yau have resolved the longstanding universality conjecture (ie limiting eigenvalues statistics do not depend on the distribution of the matrix elements). In the field of KPZ significant progress has been recently made in analysing the underlying combinatorial and integrable structure, explaining (to some extend but not fully) the links to random matrix theory.

The course will aim to familiarise students with the forefronts of some fast developing research areas and equip them with a wide range of tools that can find applications in various settings beyond the focus topics.

The course will be ideal for students who want to pursue or are pursuing doctoral studies in probability but can also be of interest to students with interests outside probability (in the second case the students are encouraged to consult with the lecturer).

Objectives: By the end of the course, the student will:
- Familiarise with rapidly developing areas of modern probability.
- Understand and be able to use key methods and concepts with wide applicability.

References:

1) “Topics in Random Matrix Theory” by Terence Tao
2) “ Log-gases and random matrices” by P. Forrester
3) “Dynamical approach to random matrix theory” by L. Erdos and H.T. Yau
4) "A pedestrian's view on interacting particle systems, KPZ universality, and random matrices” , by T. Kriecherbauer and J. Krug

Assessment: 100% by 2hr exam.

MA359 Measure Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma359)
Lecturer: Norman Zergaenge

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 hours

Assessment: examination (85%), assignments (15%)

Prerequisites: MA132 Foundations, MA222 Metric Spaces, MA244 Analysis III.

Leads To: ST318 Probability Theory, MA3D4 Fractal Geometry, MA482 Stochastic Analysis, MA496 Signal Processing, Fourier Analysis and Wavelets

Content: The modern notion of measure, developed in the late 19th century, is an extension of the notions of length, area or volume. A *measure m* is a law which assigns a number $m(A)$ to certain subsets *A* of a given space and is a natural generalization of the following notions: 1) length of an interval, 2) area of a plane figure, 3) volume of a solid, 4) amount of mass contained in a region, 5) probability that an event from *A* occurs, etc.

It originated in the real analysis and is used now in many areas of mathematics like, for instance, geometry, probability theory, dynamical systems, functional analysis, etc.

Given a measure *m*, one can define the *integral* of suitable real valued functions with respect to *m*. Riemann integral is applied to continuous functions or functions with ``few`` points of discontinuity. For measurable functions that can be discontinuous ``almost everywhere'' Riemann integral does not make sense. However it is possible to define more flexible and powerful *Lebesgue's integral* (integral with respect to *Lebesgue's measure*) which is one of the key notions of modern analysis.

The Module will cover the following topics: Definition of a measurable space and σ-additive measures, Construction of a measure form outer measure, Construction of Lebesgue's measure, Lebesgue-Stieltjes measures, Examples of non-measurable sets, Measurable Functions, Integral with respect to a measure, Lusin's Theorem, Egoroff's Theorem, Fatou's Lemma, Monotone Convergence Theorem, Dominated Convergence Theorem, Product Measures and Fubini's Theorem. Selection of advanced topics such as Radon-Nikodym theorem, covering theorems, differentiability of monotone functions almost everywhere, descriptive definition of the Lebesgue integral, description of Riemann integrable functions, *k*-dimensional measures in *n*-dimensional spaces, divergence theorem, Riesz representation theorem, etc.

Aims: To introduce the concepts of *measure* and *integral with respect to a measure*, to show their basic properties, and to provide a basis for further studies in Analysis, Probability, and Dynamical Systems.

Objectives: To gain understanding of the abstract measure theory and definition and main properties of the integral. To construct Lebesgue's measure on the real line and in *n*-dimensional Euclidean space. To explain the basic advanced directions of the theory.

Books: There is no official textbook for the course. The list below contains some of many books that may be used to complement the lectures.

Stein, E. M. and Shakarchi, R. *Real Analysis - measure theory, integration and Hilbert spaces.* (Princeton Lectures in Analysis III) Princeton University Press (2005).

Royden, H. L.: *Real Analysis*, Third Edition, Macmillan Publishing Company (1988).

Rudin, W.: *Real and Complex Analysis*, Third Edition, McGraw-Hill Book Company (1987).

Halmos, P. R.: *Measure Theory*, D. Van Nostrand Company Inc., Princeton, N.J. (1950).

Additional Resources

MA371 Qualitative Theory of ODEs

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma371)

Not Running in 2015/16

Lecturer:

Term(s):

Status for Mathematics students: Years 3 and 4: List A

Commitment: 30 lectures

Assessment: 3 hour examination

Prerequisites: MA133 Differential Equations, MA131 Analysis, MA106 Linear Algebra, MA222 Metric Spaces, and MA225 Differentiation. Also parts of MA235 Intro to Math Biology provide helpful background.

Leads To: MA424 Dynamical Systems and lots of fun areas of research!

Content:
The module presents the geometric approach to ordinary differential equations and some of the key ways in which it permits one to go well beyond the traditional approach. The emphasis is on techniques to determine the phase portrait. So the module is a natural sequel to Differential Equations.

1. Geometric approach versus explicit solutions: flow, phase portrait. Existence, uniqueness and continuity of solution to initial value problem.
2. Orbits, invariant sets, omega-limit sets; Lyapunov stability and asymptotic stability, attracting set and basin of attraction. Conservative systems. Lyapunov functions, La Salle's Invariance Principle.
3. Dynamics near equilibria: sinks and sources; Lyapunov Stability Theorems; hyperbolic equilibria, stable and unstable manifolds; linearisation theorems.
4. Periodic orbits: in 2D flows, Poincare-Bendixson theorem and Divergence test; first return map, Floquet multipliers and Lyapunov exponents; Lienard systems; Energy balance method for near-conservative systems.

5. Bifurcations of 2D flows: use of implicit function theorem, centre manifolds, normal forms and return maps.

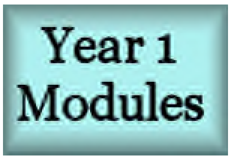
Aims:
To teach you some tools to understand the asymptotic behaviour of systems of ODEs and the ways this can change with parameters.

Objectives:
By the end of the module, students should be familiar with the geometric approach to ODEs and the tools presented, and be able to use them to determine phase portraits for some simple systems and to recognize simple bifurcations taking place in one-parameter families.

Book:
We will not follow any particular book. The most recommended is:
M Hirsch and S Smale, *Differential equations, dynamical systems and linear algebra*, Academic Press 1974.

Other books which can be useful (from easy but not covering the module to substantial but going beyond the module):
PA Glendinning, *Stability, instability and chaos*, CUP 1994.
A.C. King, J. Billingham & S.R. Otto, *Differential Equations*, CUP, 2003.
DW Jordan and P Smith, *Nonlinear ODEs*, Oxford 1987.
PG Drazin, *Nonlinear systems*, CUP 1992.
R Grimshaw, *Nonlinear ODEs*, CRC Press 1991.
DK Arrowsmith and CM Place, *Introduction to Dynamical Systems*, CUP 1990.
S Wiggins, *Introduction to applied nonlinear dynamical systems and chaos*, Springer 1990.
VI Arnold, *Ordinary Differential equations*, Springer 1973. VI Arnold, *Geometrical methods in the theory of ODEs*, Springer 1988.

Additional Resources



Year 1 regs and modules
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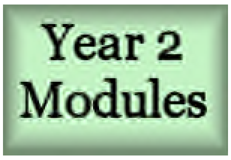
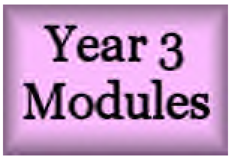
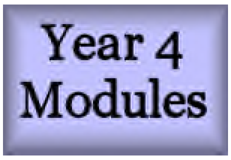


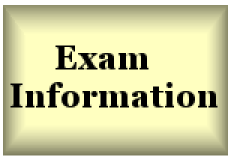
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA390 Topics in Mathematical biology

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma390)

Lecturer: Hugo van den Berg

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 one hour lectures

Assessment: 3 hour examination (100%)

Prerequisites: Any one or more of MA235 Introduction to Mathematical Biology, MA250 Partial Differential Equations and MA254 Theory of ODEs are recommended.

Content: The module will consider ideas and techniques used in the three areas of biological research:

1. Evolutionary genetics and dynamics
2. Bioinformatics and statistics
3. Functional biology

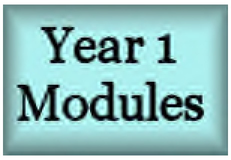
Particular attention will be paid to the interfaces between these three areas. For instance, the merging of (1) and (2) into the more general discipline of quantitative genomics, and the synergy of (2) and (3) forms the basis of what in recent years has become known as Systems Biology.

Aims: To introduce ideas and techniques of mathematical modelling in biology.

Objectives: To gain an insight into evolutionary dynamics, genomics (e.g. sequence and QTL analyses), and models of biological systems; to consolidate basic mathematical techniques used in these approaches, such as ODEs, DEs, Markov Chains, and Optimal Control.

Books: The core text for this module is:
Evolutionary Dynamics: The Mathematics of Genes and Traits Institute of Physics.
In addition, the following are highly recommended:
Maynard-Smith, *Evolutionary Genetics*, OUP.
Bell, *Selection: The Mechanism of Evolution*, OUP.
Rice, *Evolutionary Theory: Mathematical and Conceptual Foundations*, Sinauer.

Additional Resources



Year 1 regs and modules
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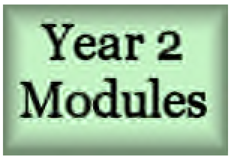

Year 2 regs and modules
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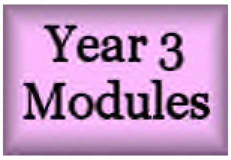
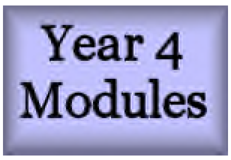


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

Exam Information

Past Exams

Core module averages

MA397 Consolidation

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma397)
Lecturer: Nicholas Jackson

Term(s): Term 1

Status for Mathematics students: Core for third year Pass Degree students. **Not Available** to others

Commitment: Weekly meetings

Assessment: Wholly based upon the student's portfolio of written assignments, performance in two short tests, and his/her explanations in the tutorials. The tutorials themselves form an essential part of the assessment process.

Prerequisites: None

Leads To: 3rd year modules

Content: The tutor selects problems related to first year modules and to second year modules where the student's record indicates that further study is desirable. Each week, the student receive an assignment of written work to be handed in. At the following tutorial, the student and the tutor discuss the student's answers and related material.

Aims: To provide individual attention for students recommended by the Second Year Exam Board to improve prospects of a good honours degree.

Objectives: To improve upon your understanding of the material from the first two years, focusing primarily on the topics that you struggled with first time around.

Books: Recommendations will depend upon the individual. But, a comprehensive book list will be provided at the start of the course.

Additional Resources

Year 1 Modules

Year 1 regs and modules

G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules

G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules

G100 G103

Year 4 Modules

Year 4 regs and modules

G103

Exam Information

Past Exams

Core module averages

MA398 Matrix Analysis and Algorithms

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma398)
Lecturer: Stefan Grosskinsky

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: Exam (85%) Assignments (15%)

Prerequisites: Core module of the first and second year, in particular MA106 Linear Algebra and MA225 Differentiation, are sufficient. Helpful but not mandatory is some knowledge of numerical concepts as accuracy, iteration, and stability as provided in MA228 Numerical Analysis.

Leads To: A few notions used for the analysis are shared with MA3G7 Functional Analysis I. With respect to implementation and software issues but also towards optimisation problems the module MA4G7 Computational Linear Algebra and Optimization is recommended. A nice application area where various methods provided in this module are needed are numerical methods for partial differential equations, MA3H0 Numerical Analysis and PDEs

Content: Large scale problems in linear algebra as solving systems of linear equations, least-squares problems, and eigenvalue problems lie at the heart of many algorithms in scientific computing and require highly efficient solvers. The module will be based around understanding the mathematical principles underlying the design and the analysis of effective methods and algorithms.

Aims: Understanding how to construct algorithms for solving some problems central in numerical linear algebra and to analyse them with respect to accuracy and computational cost.

Objectives: At the end of the module you will familiar with concepts and ideas related to:

1. various matrix factorisations as the theoretical basis for algorithms,
2. assessing algorithms with respect to computational cost,
3. conditioning of problems and stability of algorithms,
4. direct versus iterative methods.

Books:

AM Stuart and J Voss, *Matrix Analysis and Algorithms*, script.

G Golub and C van Loan, *Matrix Computations*, 3. ed., Johns Hopkins Univ. Press, London 1996.

NJ Higham, *Accuracy and Stability of Numerical Algorithms*, SIAM 1996.

RA Horn and CR Johnson, *Matrix Analysis*, Cambridge University Press 1985.

D Kincaid and W Cheney, *Numerical Analysis*, 3. ed., AMS 2002.

LN Trefethen and D Bau, *Numerical Linear Algebra*, SIAM 1997.

Additional Resources

Year 1 Modules

Year 1 regs and modules

G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules

G100 G103 GL11 G1NC

MA3D4 Fractal Geometry

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3d4)
Lecturer: András Máthé

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one-hour lectures

Assessment: Assignments 15%, 3 hour Examination 85%

Prerequisites: MA222 Metric Spaces

Leads To:

Content: Fractals are geometric forms that possess structure on all scales of magnification. Examples are the middle third Cantor set, the von Koch snowflake curve and the graph of a nowhere differentiable continuous function.

The main focus of the module will be the mathematical theory behind fractals, such as the definition and properties of the Hausdorff dimension, which is a number quantifying how ``rough'' the fractal is and which reduces to the usual dimension when applied to Euclidean space. However, more recent developments will be included, such as iterated function systems (used for image compression) where we study how a fractal is approximated by other compact subsets.

Books: K. Falconer, Fractal geometry: mathematical foundations and applications, Wiley, 1990 or 2003. (We shall cover much of the first half of this book.)

Additional Resources

MA3D5 Galois Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3d5)
Lecturer: Inna Capdeboscq

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 lectures + assessment sheets

Assessment: 3-hour examination (85%), best 3 out of 4 assessed worksheets (15%).

Prerequisites: MA106 Linear Algebra, MA249 Algebra II: Groups and Rings

Leads To:

Content: Galois theory is the study of solutions of polynomial equations. You know how to solve the quadratic equation $ax^2 + bx + c = 0$ by completing the square, or by that formula involving plus or minus the square root of the discriminant $b^2 - 4ac$. The cubic and quartic equations were solved ``by radicals'' in Renaissance Italy. In contrast, Ruffini, Abel and Galois discovered around 1800 that there is no such solution of the general quintic. Although the problem originates in explicit manipulations of polynomials, the modern treatment is in terms of field extensions and groups of ``symmetries'' of fields. For example, a general quintic polynomial over Q has five roots $\alpha_1 . . . . . \alpha_5$, and the corresponding symmetry group is the permutation group S_5 on these.

Aims: The course will discuss the problem of solutions of polynomial equations both in explicit terms and in terms of abstract algebraic structures. The course demonstrates the tools of abstract algebra (linear algebra, group theory, rings and ideals) as applied to a meaningful problem.

Objectives: By the end of the module the student should understand

1. Solution by radicals of cubic equations and (briefly) of quartic equations.
2. The characteristic of a field and its prime subfield. Field extensions as vector spaces.
3. Factorisation and ideal theory in the polynomial ring k[x]; the structure of a simple field extension.
4. The impossibility of trisecting an angle with straight-edge and compass.
5. The existence and uniqueness of splitting fields.
6. Groups of field automorphisms; the Galois group and the Galois correspondence.
7. Radical field extensions; soluble groups and solubility by radicals of equations.
8. The structure and construction of finite fields.

Books: DJH Garling, *A course in Galois theory*, CUP.

IN Stewart, *Galois Theory*, Chapman and Hall.

Additional Resources

MA3D9 Geometry of curves and Surfaces

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3d9)

Lecturer: Lucas Ambrozio

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3-hour examination (100%)

Prerequisites: MA225 Differentiation, MA231 Vector Analysis Some familiarity with MA222 Metric Spaces may be useful but not essential.

Leads To:

Content: This will be an introduction to some of the ``classical'' theory of differential geometry, as illustrated by the geometry of curves and surfaces lying (mostly) in 3-dimensional space. The manner in which a curve can twist in 3-space is measured by two quantities: its curvature and torsion. The case a surface is rather more subtle. For example, we have two notions of curvature: the gaussian curvature and the mean curvature. The former describes the intrinsic geometry of the surface, whereas the latter describes how it bends in space. The gaussian curvature of a cone is zero, which is why we can make a cone out of a flat piece of paper. The gaussian curvature of a sphere is strictly positive, which is why planar maps of the earth's surface invariably distort distances. One can relate these geometric notions to topology, for example, via the so-called Gauss-Bonnet formula. This is mostly mathematics from the first half of the nineteenth century, seen from a more modern perspective. It eventually leads on to the very general theory of manifolds.

Aims: To gain an understanding of Frenet formulae for curves, the first and second fundamental forms of surfaces in 3-space, parallel transport of vectors and gaussian curvature. To apply this understanding in specific examples.

Books: John McCleary, *Geometry from a differential viewpoint* Cambridge University Press 1994.

Dirk J. Struik, *Lectures on classical differential geometry* Addison-Wesley 1950.

M Do Carmo, *Differential geometry of curves and surfaces*, Prentice Hall.

Additional Resources

MA3E1 Groups & Representations

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3e1)
Lecturer: Miles Reid

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one-hour lectures

Assessment: Assigned work/tests 15%. Three-hour written exam 85%

Prerequisites: The Group theory and linear algebra taught in core modules

Leads To:

Content: The concept of a group is defined abstractly (as set with an associative binary operation, a neutral element, and a unary operation of inversion) but is better understood through concrete examples, for instance

- permutation groups
- matrix groups
- groups defined by generators and relations. All these concrete forms can be investigated with computers. In this module we will study groups by
- finding matrix groups to represent them
- using matrix arithmetic to uncover new properties. In particular, we will study the irreducible characters of a group and the square table of complex numbers they define. Character tables have a tightly-constrained structure and contain a great deal of information about a group in condensed form. *The emphasis of this module will be on the interplay of theory with calculation and examples.*

Aims: To introduce representation theory of finite groups in a hands-on fashion.

Objectives: To enable students to:

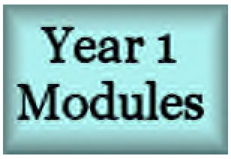
- understand matrix and linear representations of groups and their associated modules,

- compute representations and character tables of groups, and
- know the statements and understand the proofs of theorems about groups and representations covered in this module.

Books:

We will work through printed notes written by the lecturer.
A nice book that we shall not use is:
G James & M Liebeck, *Representations and Characters of Groups*, Cambridge University Press, 1993. Second edition, 2001. (IBSN: 052100392X).

Additional Resources



Year 1 regs and modules
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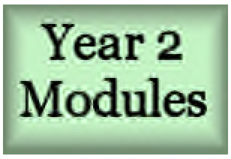

Year 2 regs and modules
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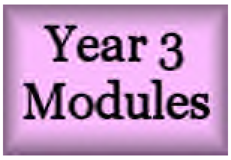

Year 3 regs and modules
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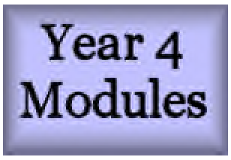
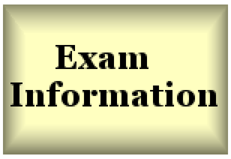


Year 4 regs and modules
G103



Past Exams
Core module averages

MA3E5 History of Mathematics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3e5)
Lecturer: Jeremy Gray

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 one-hour lectures. Students are to submit three essays

Assessment: One essay (500 words, 14%) by week 5. One essay (1,500 words, 26%) by week 8. One essay (2,000 words, 60%) at the start of Term 2. The deadline is enforced as described in the Exams and Assessment section of the Course Handbook.

Prerequisites: Prerequisites: MA133 Differential Equations, MA131 Analysis and MA106 Linear Algebra.

Leads To: Leads To: In terms of the mathematics, the course introduces some of the topics in MA250 Introduction to Partial Differential Equations and MA371 Qualitative Theory of ODEs in their historical settings, but will be studied independently.

Content: Mathematicians seek answers to questions, problems, and challenges of various kinds. They have at their disposal methods that may or may not work, and they get answers that may or may not be any use. This is clearest in mathematical physics (e.g. when a power series converges too slowly to be any help) but it can also be true in pure mathematics. This is a historical course about getting good answers to good problems in mathematics.

Aims: The module aims to:

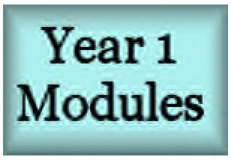
- consider topics in the history of ordinary and partial differential equations from their introduction in the 17th century to the early 20th century;
- discuss what was taken to be so important about them.

Objectives:

- To develop a critical sense of what was, and even what is, important and exciting about mathematics and its evolution.
- To raise questions about the rigour in mathematics and its relation to problem solving.

Books: A full set of Lecture Notes will be provided. There is no book on the topic, and in that sense the course will present the result of ongoing historical research. There are some specialist treatments of individual topics, and these will be pointed out as and when they are relevant.

Additional Resources



Year 1 regs and modules
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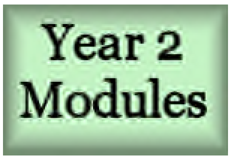

Year 2 regs and modules
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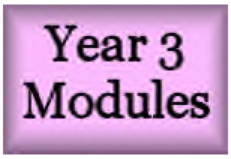

Year 3 regs and modules
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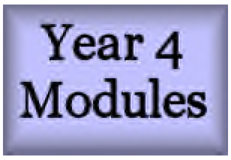
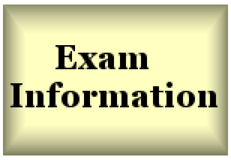


Year 4 regs and modules
G103



Past Exams
Core module averages

History of Maths 2016 Results

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3e5/2016results)
Please find below your final marks for the 2015/16 History of Maths module which have changed for some of the students registered on it since the Exam Board first met due to an unfortunate administrative error. Any finalist for whom this has changed a Board decision will have been contacted already by email, all students whose marks have changed will have been looked at again by the Board.

The Maths Department is extremely sorry for any inconvenience or worry caused by this, we are putting in place procedures so that this will not happen again in future years, and are very aware that, in this instance, something went wrong that shouldn't have. Apologies.

Dave

Dr. David Wood
Director of Undergraduate Studies (Maths)

You are not signed in

This page is designed to display information specific to you, so you need to sign in first.

MA3F1 Introduction to Topology

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3f1)
Lecturer: Saul Schleimer

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 one-hour lectures

Assessment: One 3-hour examination (85%), assignments (15%)

Prerequisites: MA129 Foundations, MA242 Algebra I, MA222 Metric Spaces

Leads To: MA3H6 Algebraic Topology,MA3H5 Manifolds, MA3F2 Knot Theory.

Content:
Topology is the study of properties of spaces invariant under continuous deformation. For this reason it is often called ``rubber-sheet geometry''. The module covers: topological spaces and basic examples; compactness; connectedness and path-connectedness; identification topology; Cartesian products; homotopy and the fundamental group; winding numbers and applications; an outline of the classification of surfaces.

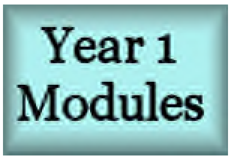
Aims:
To introduce and illustrate the main ideas and problems of topology.

Objectives:
To explain how to distinguish spaces by means of simple topological invariants (compactness, connectedness and the fundamental group); to explain how to construct spaces by gluing and to prove that in certain cases that the result is homeomorphic to a standard space; to construct simple examples of spaces with given properties (eg compact but not connected or connected but not path connected).

Books:
Chapter 1 of Allen Hatcher's book Algebraic Topology

MA Armstrong *Basic Topology* Springer (recommended but not essential).

Additional Resources



Year 1 regs and modules
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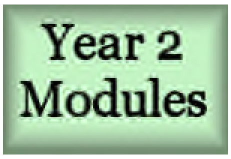

Year 2 regs and modules
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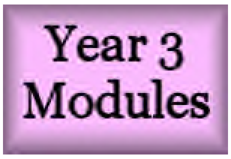

Year 3 regs and modules
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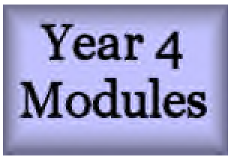

Year 4 regs and modules
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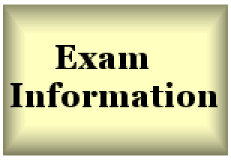


Past Exams

Core module averages

MA3G7 Functional Analysis I

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g7)
Lecturer: Richard Sharp

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour examination

Prerequisites: You should revise the material from MA225 Differentiation and MA244 Analysis III; MA222 Metric Spaces would be useful but not essential; MA359 Measure Theory would be a natural course to take in parallel.

Leads To: MA3G8 Functional Analysis II, MA4A2 Advanced PDEs, MA4L3 Large Deviation theory.

Content: This is essentially a module about infinite-dimensional Hilbert spaces, which arise naturally in many areas of applied mathematics. The ideas presented here allow for a rigorous understanding of Fourier series and more generally the theory of Sturm-Liouville boundary value problems. They also form the cornerstone of the modern theory of partial differential equations.

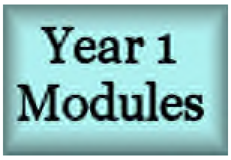
Hilbert spaces retain many of the familiar properties of finite-dimensional Euclidean spaces ($\mathbb{R}^n$) - in particular the inner product and the derived notions of length and distance - while requiring an infinite number of basis elements. The fact that the spaces are infinite-dimensional introduces new possibilities, and much of the theory is devoted to reasserting control over these under suitable conditions.

The module falls, roughly, into three parts. In the first we will introduce Hilbert spaces via a number of canonical examples, and investigate the geometric parallels with Euclidean spaces (inner product, expansion in terms of basis elements, etc.). We will then consider various different notions of convergence in a Hilbert space, which although equivalent in finite-dimensional spaces differ in this context. Finally we consider properties of linear operators between Hilbert spaces (corresponding to the theory of matrices between finite-dimensional spaces), in particular recovering for a special class of such operators (compact self-adjoint operators) very similar results to those available in the finite-dimensional setting.

Throughout the abstract theory will be motivated and illustrated by more concrete examples.

Books: A useful book to use as an accompanying reference is:
BP Rynne & MA Youngson, *Linear Functional Analysis*, Springer-Verlag, London, 2000.

Additional Resources



Year 1 regs and modules
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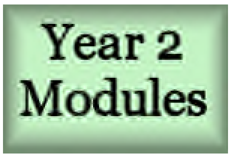

Year 2 regs and modules
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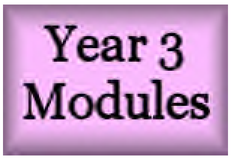


Year 3 regs and modules
G100 G103

MA3H1 Topics in Number Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h1)

Not Running in 2015/16

Lecturer:

Term(s):

Status for Mathematics students: List A

Commitment: 30 lectures, plus a willingness to work hard at the homework

Assessment: 15% by a number of assessed worksheets, 85% by 3-hour examination

Prerequisites: First-year mathematics and common sense. This module is **independent** of MA246 Number Theory and can be taken regardless of whether or not you have done MA246.

Leads To: MA3A6 Algebraic Number Theory, MA426 Elliptic Curves.

Content: We will cover the following topics:

1. Review of factorisation, divisibility, Euclidean Algorithm, Chinese Remainder Theorem.
2. Congruences. Structure on $/m$ and U_m. Theorems of Fermat and Euler. Primitive roots.
3. Quadratic reciprocity, Diophantine equations
4. Tonelli-Shanks, Fermat's factorization, Quadratic Sieve.
5. Introduction to Cryptography (RSA, Diffie-Hellman)
6. p-adic numbers, Hasse Principle
7. Geometry of numbers, sum of two and four squares
8. Irrationality and trancendence
9. Binary quadratic forms, genus theory (ONLY if time allows!)

Books:

R. P. Burn, A Pathway into Number Theory, Cambridge University Press, 1997.

H. Davenport, The Higher Arithmetic, Cambridge University Press.

G. H. Hardy and E. M. Wright, An Introduction to the Theory of Numbers, Oxford University Press, 1979.

K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, Springer-Verlag, 1990.

I. Niven, H. S. Zukerman and H. L. Montgomery, An Introduction to the Theory of Numbers, John Wiley, 1991.

H. E. Rose, A Course in Number Theory, Oxford University Press, 1988.

W. Stein, Elementary Number Theory: Primes, Congruences, and Secrets, Springer-Verlag, 2008. Online version available from `http://modular.math.washington.edu/ent/ent.pdf`

Additional Resources

MA3H3 Set Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h3)
Lecturer: András Máthé

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour exam 100%

Prerequisites: MA132 Foundations or PH126 Starting Formal Logic. Some exposure to at least one of MA222 Metric Spaces, MA359 Measure Theory or PH210 Symbolic Logic is also recommended

Leads To:

Content: Set theoretical concepts and formulations are pervasive in modern mathematics. For this reason it is often said that set theory provides a foundation for mathematics. Here `foundation' can have multiple meanings. On a practical level, set theoretical language is a highly useful tool for the definition and construction of mathematical objects. On a more theoretical level, the very notion of a foundation has definite philosophical overtones, in connection with the reducibility of knowledge to agreed first principles.

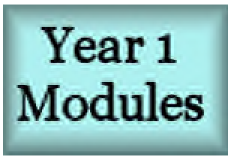
The module will commence with a brief review of naive set theory. Unrestricted set formation leads to various paradoxes (Russell, Cantor, Burali-Forti), thereby motivating axiomatic set theory. The Zermelo-Fraenkel system will be introduced, with attention to the precise formulation of axioms and axiom schemata, the role played by proper classes, and the cumulative hierarchy picture of the set theoretical universe. Transfinite induction and recursion, cardinal and ordinal numbers, and the real number system will all be developed within this framework. The Axiom of Choice, and various equivalents and consequences, will be discussed; various other principles also known to be independent of Zermelo-Fraenkel set theory, such as the Continuum Hypothesis and the existence of Inaccessible Cardinals, will be touched on.

Books:

- *Set Theory*, T. Jech (a comprehensive advanced text which goes well beyond the above syllabus)

- *Notes on set theory*, Y. Moschovakis
- *Elements of set theory*, H. Enderton
- *Introduction to set theory*, K. Hrbacek and T. Jech

Additional Resources



Year 1 regs and modules
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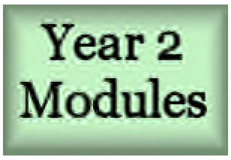

Year 2 regs and modules
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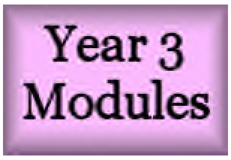

Year 3 regs and modules
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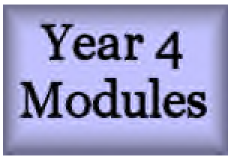
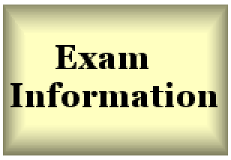


Year 4 regs and modules
G103



Past Exams
Core module averages

MA3H4 Random Discrete Structures

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h4)

Not Running in 2015/16

Lecturer:

Term(s):

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour exam 85%, assigned exercises 15%

Prerequisites: MA132 Foundations or PH126 Starting Formal Logic. Some exposure to at least one of MA222 Metric Spaces, MA359 Measure Theory or PH210 Symbolic Logic is also recommended

Leads To:

Content: Random discrete structures such as random graphs or matrices play a crucial role in discrete mathematics, because they enjoy properties that are difficult (or impossible) to obtain via deterministic constructions. For example, random structures are essential in the design of algorithms or error correcting codes. Furthermore, random discrete structures can be used to model a large variety of objects in physics, biology, or computer science (e.g., social networks). The goal of this course is to convey the most important models and the main analysis techniques, as well as a few instructive applications. Topics include

- fundamentals of discrete probability distributions,
- techniques for the analysis of rare events,
- random trees and graphs,
- applications in statistical mechanics,
- sampling and rapid mixing,
- applications in efficient decoding. The module is suitable for students of mathematics or discrete mathematics.

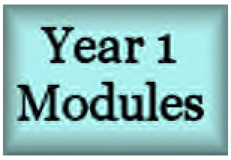
Aims:

- To acquire knowledge of the basic phenomena that occur in random discrete structures.
- To gain competence in using basic techniques such as the first and second moment method.
- To understand large deviations phenomena.
- To be in a position to apply random structures in physics or computer science.

Books:

Alon, Spencer: The probabilistic method. Wiley 2000. Dembo, Montanari: Gibbs measures and phase transitions on sparse random graphs. Stanford 2009. Durrett: Random graph dynamics. Combridge 2007. Janson, Luczak, Rucinski: Random graphs. Wiley 2000.

Additional Resources



Year 1 regs and modules
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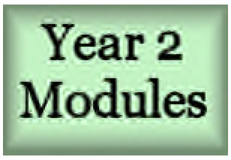

Year 2 regs and modules
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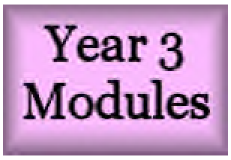

Year 3 regs and modules
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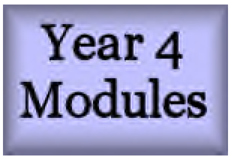
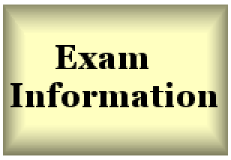


Year 4 regs and modules
G103



Past Exams
Core module averages

MA3H5 Manifolds

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h5)
Lecturer: Brian Bowditch

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 hours

Assessment: Three hour examination (100%)

Prerequisites: Basic theory of differentiation, including statements (though not proofs) of Inverse and Implicit Function Theorems. Integration in several variables. MA225 Differentiation, Basic topology, including compactness and connectedness, MA222 Metric Spaces, Basic theory of differentiation, including statements (though not proofs) of Inverse and Implicit Function Theorems.

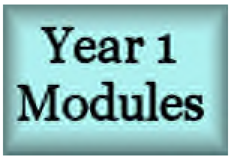
Leads To: MA4C0 Differential Geometry.
Also useful for:
MA4E0 Lie groups
It might also be a useful complement to the Year 3 module:
MA3D9 Geometry of Curves and Surfaces.

Content:
Smooth manifolds are generalisations of the notion of curves and surfaces R^3 and provide a rigorous mathematical concept of space as well as a natural setting for analysis. They form a fundamental part of modern mathematics and are used widely in pure and applied subjects such as differential geometry, general relativity and partial differential equations. Almost all the manifolds discussed in the course will be assumed to have a smooth structure. This allows us to perform the standard operations of differentiation in a very general context. We will begin by discussing manifolds embedded in euclidean space, R^n. We develop some of the basic notions such as smooth maps and tangent spaces in this context. We go on to describe the notion of an abstract manifold, and explain how these concepts generalise. We discuss basic concepts of orientability, differential forms and integration. Time permitting, we will aim to give a proof of the general form of Stokes's Theorem. We may briefly touch on subjects such as riemannian manifolds and Lie groups. These are the subject of dedicated courses in the 4th year.

Syllabus:
Manifolds in euclidean space, smooth maps, tangent spaces, immersions and submersions, tangent and normal bundles, orientations, abstract manifolds, vector bundles, partitions of unity, differential forms, integration, Stokes's theorem.

Books:
Tu, L. W. An Introduction to Manifolds, Springer-Verlag
Lee, J .M. Introduction to Smooth Manifolds, Springer-Verlag
Warner, F. Foundations of differentiable manifolds and Lie groups, Springer-Verlag
Boothby, W. An introduction to differentiable manifolds and Riemannian geometry, Academic Press

Additional Resources



Year 1 regs and modules
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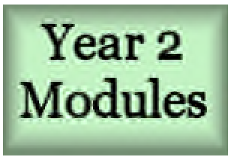
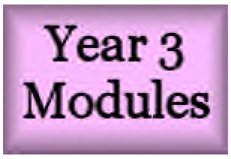
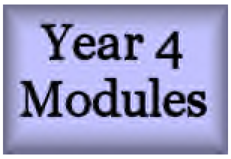


Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

Exam Information

Past Exams

Core module averages

MA3J1 Tensors, Spinors and Rotations

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3j1)

Not Running 2016/17

Lecturer: Dmitriy Rumynin

Term(s): 2

Status for Mathematics students: List A

Commitment: 30 hours

Assessment: Three hour examination (85%), coursework (15%)

Prerequisites: MA251 Algebra I: Advanced Linear Algebra and MA249 Algebra II

Leads To and/or related to:
MA3E1 Groups & Representations, MA3H6 Algebraic Topology, MA377 Rings and Modules, MA4C0 Differential Geometry, MA4E0 Lie Groups and MA4J1 Continuum Mechanics

Content:

This module will be in the spirit of Algebra-I rather than Algebra-II. In fact, it could have even been called Very Advanced Linear Algebra. It will focus on explicit calculations with various linear algebraic objects, such as multilinear forms, which are a generalised version of linear functionals and bilinear forms. It could be useful in a range of modules.

Quaternions were discovered by Hamilton in 1843. We will introduce quaternions and develop computational techniques for 3D and 4D orthogonal transformations.

The word tensor was introduced by Hamilton at the time of discovery of quaternions. It used to mean the quaternionic absolute value. It acquired its modern meaning only in 1898, by which time Ricci had developed his Theory of Curvature (a prime example of tensor in Geometry). Later tensors spread not only to Algebra and Topology but also to some faraway disciplines such as Continuum Mechanics (elasticity tensor) and General Relativity (stress-energy tensor). Our study of tensors will concentrate on understanding the concepts and computation: we will not have time to develop any substantial applications.

When Elie Cartan discovered spinors in 1913, he could hardly imagine the role they would play in Quantum Physics. In 1928 Dirac wrote his celebrated electron equation, and since then there was no way back for spinors. According to Atiyah, “No one fully understands spinors. Their algebra is formally understood but their general significance is mysterious. In some sense they describe the “square root” of geometry and, just as understanding the square root of -1 took centuries, the same might be true of spinors.”

As with tensors, our study of spinors will concentrate on understanding the concepts and computation: we will not have time to do any Physics. We plan to finish the module with Bott Periodicity for Clifford algebras.

Objectives:
This course will give the student a solid grounding in tensor algebra which is used in a wide range of disciplines.

Books:
There will be lecture notes. Some great books that the module will follow locally are:
Rotations, Quaternions, and Double Groups, by Simon L Altmann
The Algebraic Theory of Spinors, by Claude Chevalley
The Construction and Study of Certain Important Algebras, by Claude Chevalley
Rethinking Quaternions, by Ron Goldman
Quick Introduction to Tensor Analysis, by Ruslan Shapirov
Tensor Spaces and Exterior Algebras, by Takeo Yokonuma

Additional Resources

MA372 Reading Course

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma372)
Term(s): Terms 1-2

Status for Mathematics students: List A

Commitment: Mostly independent study with guidance from staff member offering the module

Assessment: 100% by 3 hour exam

Content:
This scheme is designed to allow any student to offer for exam any reasonable piece of mathematics not covered by the lecture modules, for example a 3rd/4th year or M.Sc. module given at Warwick in a previous year. Any topic approved for one student will automatically be brought to the attention of the other students in the year. Note that a student offering this option will be expected to work largely on his or her own.

The aims of this option are (a) to extend the range of mathematical subjects available for examination beyond those covered by the conventional lecture modules, and (b) to encourage the habit of independent study. In the following outline regulations, the term ``book'' includes such items as published lecture notes, one or more articles from mathematical journals, etc.

1. A student wishing to offer a book for a reading module must first find a member of staff willing to act as moderator. The moderator will be responsible for obtaining approval of the module from the Director of Undergraduate Studies of the Mathematics Department, and for circulating a detailed syllabus to all 3rd and 4th year Mathematics students before the end of Term 1 registrations (week 3).

2. The moderator will be responsible for setting a three-hour exam paper, to be taken during one of the examination sessions in Term 3.

3. The mathematical level and content of a reading module must be at least that of a standard 15 CATS 3rd Year Mathematics module. A reading module must not overlap significantly with any other module in the university available to 3rd Year Mathematics students.

4. Students may not take more than one reading module in any one year (MA372, MA472 or a reading module with its own code).

Additional Resources

MA395 Essay

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma395)
Organiser: Roman Kotecký

Term(s): Terms 1-2

Status for Mathematics students: List A - a student may offer at most one MA395 essay. Not available to 4th Year MMath students

Commitment:

Assessment: Essay 80%, Oral Presentation 20%

Aims: The 3rd year essay offers the opportunity of producing an original and personal account of a mathematical topic of your own choice going beyond the scope of existing lecture modules. It will test your ability to understand new mathematical ideas without detailed guidance, to use the library in a resourceful and scholarly way, and to produce a personal account of a piece of maths. The essay should be 6,000-8,000 words in length, and comparable in content to ten lectures from a 3rd year maths module. As a rough guide, you should expect to spend at least 100 hours on this option. You are supposed to find a member of staff willing to give you, and advise on, a choice of the topic (to learn about scientific interests of members of staff in the domain of mathematics you are interested in is already a part of your task) who will be also responsible for the marking and suggesting the second marker.

Deadlines: You are supposed to find your supervisor within the first weeks of Term 1 and register for your essay (name of the supervisor and title of the essay) at the undergraduate office before the end of week 5.

The essay must normally be submitted to the Undergraduate Office by 12:00 noon on Thursday of the first week of Term 3. This deadline is enforced by the mechanism described in the Course Handbook section on Assessment. The oral presentation should be completed in week 3 or 4 of Term 3.

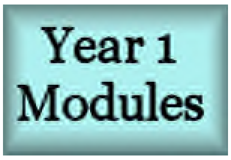
Essay: The essay makes up 80% of the mark for this module. It will be marked on various aspects such as presentation, referencing, content, understanding and originality. The markers will be given more guidance, but they do have the flexibility to give more weight to some aspects than others depending on whether the essay is, for example, an exposition of a known result or an investigation of an original problem. Cases of plagiarism will be dealt with severely, so please make sure that you reference material that has been taken from elsewhere correctly (see, for example, the documents listed in the resources for the second year essay).

Oral Presentation: 20% of the module mark comes from an oral presentation. This presentation should consist of a talk of approximately 20-30 minutes length followed by questions. The whole process should take less than one hour. You should arrange the time and venue for the talk with the supervisor of the essay, and it is usual for both the supervisor and second marker to attend.

The purpose of the presentation is to demonstrate your understanding of the material contained within the essay and to clarify anything that the examiners feel requires further explanation; the marking will reflect this. With this in mind, in preparation you should concentrate on organising the content in a coherent manner (and choosing which aspects of the essay to concentrate on and which to leave out). You should not spend a lot of time producing a glossy presentation - all that is required is a simple but clear presentation and a willingness to answer questions on the content of your essay. If you wish you may use the blackboard, or a short handout, or uncomplicated slides.

The oral is not supposed to be a performance, and students who are nervous or find public speaking difficult will not be at a disadvantage. Marks will be given for clarity and organisation of the presentation, and for answering questions about and demonstrating understanding of the material in the essay.

Tip: You should also bear in mind that 20 to 30 minutes is not actually a very long time (as you may appreciate from your second year essay presentation), and should certainly try to make sure that you have a dry run through beforehand, perhaps in front of housemates.



Year 1 regs and modules
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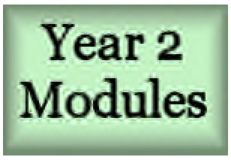
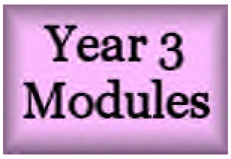
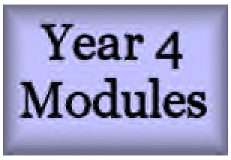


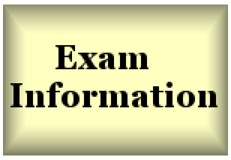
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA377 Rings and Modules

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma377)
Lecturer: Marco Schlichting

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 85% by 3-hour examination 15% coursework

Prerequisites: MA106 Linear Algebra, familiarity with elementary group theory and the ring theory part of MA249 Algebra II: Groups and Rings is desirable

Leads To:

Content: A ring is an important fundamental concept in algebra and includes integers, polynomials and matrices as some of the basic examples. Ring theory has applications in number theory and geometry. A module over a ring is a generalization of vector space over a field. The study of modules over a ring R provides us with an insight into the structure of R. In this module we shall develop ring and module theory leading to the fundamental theorems of Wedderburn and some of its applications.

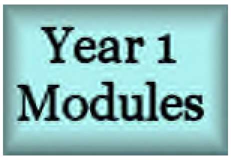
Aims: To realise the importance of rings and modules as central objects in algebra and to study some applications.

Objectives: By the end of the course the student should understand:

- The importance of a ring as a fundamental object in algebra.
- The concept of a module as a generalisation of a vector space and an Abelian group.
- Constructions such as direct sum, product and tensor product.
- Simple modules, Schur's lemma.
- Semisimple modules, artinian modules, their endomorphisms. Examples.
- Radical, simple and semisimple artinian rings. Examples.
- The Artin-Wedderburn theorem.
- The concept of central simple algebras, the theorems of Wedderburn and Frobenius.

Books: Recommended Reading:
Abstract Algebra by David S. Dummit, Richard M. Foote, ISBN: 0471433349
Noncommutative Algebra (Graduate Texts in Mathematics) by Benson Farb, R. Keith Dennis, ISBN: 038794057X

Additional Resources



Year 1 regs and modules
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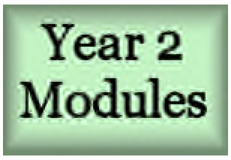

Year 2 regs and modules
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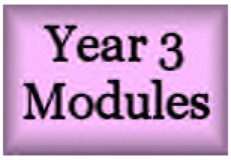
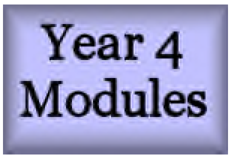
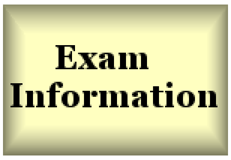


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA3A6 Algebraic Number Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3a6)
Lecturer: Samir Siksek

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one-hour lectures.

Assessment: Three-hour examination (85%), assignments (15%)

Prerequisites: MA251 Algebra I, MA249 Algebra II

Leads To:

Content: Algebraic number theory is the study of algebraic numbers, which are the roots of monic polynomials

$$x^n + a_{n-1}x^{n-1} \ \cdots + a_1x + a_0$$

with rational coefficients, and algebraic integers, which are the roots of monic polynomials with integer coefficients. So, for example, the n^th roots of natural numbers are algebraic integers, and so is

$$\frac{\sqrt{5} \ + \ 1}{2}$$

The study of these types of numbers leads to results about the ordinary integers, such as determining which of them can be expressed as the sum of two integral squares, proving that any natural number is a sum of four squares and, as a much more advanced application, which combines algebraic number theory with techniques from analysis, the proof of Fermat's Last Theorem.

One of the differences between rings of algebraic integers and the ordinary integers, is that we do not always get unique factorization into irreducible elements. For example, in the ring

$$\{a + b\sqrt{-5} \ \mid \ a, b \ \in \ Z \ \},$$

it turns out that 6 has two distinct factorizations into irreducibles:

$$6 = 2 \times \ 3$$

and

$$6 = (1 - \sqrt{-5}) \times (1 + \sqrt{-5}).$$

However, we do get a unique factorization theorem for ideals, and this is the central result of the module.

This main result will be followed by some more straightforward geometric material on lattices in n, with applications to sums of squares theorems, and then finally various groups associated with the ideals in a number field.

- Algebraic numbers, algebraic integers, algebraic number fields, integral bases, discriminants, norms and traces.
- Quadratic and cyclotomic fields.
- Factorization of algebraic integers into irreducibles, Euclidean and principal ideal domains.
- Ideals, and the prime factorization of ideals.
- Lattices.
- Minkowski's Theorem. Application: every integer is the sum of four squares.
- The geometric representation of algebraic numbers.
- The ideal class group.

Aims: To demonstrate that uniqueness of factorization into irreducibles can fail in rings of algebraic integers, but that it can be replaced by the uniqueness of factorization into prime ideals.

To introduce some geometric lattice-theoretic techniques and their applications to algebraic number theory.

Objectives: By the end of the course students will:

- be able to compute norms and discriminants and to use them to determine the integer rings in algabraic number fields;
- be able to factorize ideals into prime ideals in algebraic number fields in straightforward examples;
- understand the proof of Minkowski's Theorem on lattices, and be able to apply it, for example, to prove that all positive integers are the sum of four squares.

Books:

This module is based on the book *Algebraic Number Theory and Fermat's Last Theorem*, by I.N. Stewart and D.O. Tall, published by A.K. Peters (2001). The contents of the module forms a proper subset of the material in that book. (The earlier edition, published under the title *Algebraic Number Theory*, is also suitable.)

For alternative viewpoints, students may also like to consult the books *A Brief Guide to Algebraic Number Theory*, by H.P.F. Swinnerton-Dyer (LMS Student Texts # 50, CUP), or *Algebraic Number Theory*, by A. Fröhlich and M.J. Taylor (CUP).

Additional Resources

MA3B8 Complex Analysis

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3b8)
Lecturer: Filip Rindler

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one-hour lectures

Assessment: 3-hour examination

Prerequisites: MA225 Differentiation MA244 Analysis III, and MA231 Vector Analysis. MA3F1 Introduction to Topology would be helpful but not essential.

Leads To: MA475 Riemann Surfaces.

Content: The course focuses on the properties of differentiable functions on the complex plane. Unlike real analysis, complex differentiable functions have a large number of amazing properties, and are very ``rigid'' objects. Some of these properties have been explored already in Vector Analysis. Our goal will be to push the theory further, hopefully revealing a very beautiful classical subject.

We will start with a review of elementary complex analysis topics from vector analysis. This includes complex differentiability, the Cauchy-Riemann equations, Cauchy's theorem, Taylor's and Liouville's theorem, Laurent expansions. Most of the course will be new topics: Winding numbers, the generalized version of Cauchy's theorem, Morera's theorem, the fundamental theorem of algebra, the identity theorem, classification of singularities, the Riemann sphere and Weierstrass-Casorati theorem, meromorphic functions, Rouche's theorem, integration by residues.

Books:

Stewart and Tall, *Complex Analysis: (the hitchhiker's guide to the plane)*, (Cambridge University Press).

Conway, *Functions of one complex variable*, (Springer-Verlag).

Ahlfors, *Complex Analysis: an introduction to the theory of analytic functions of one complex variable*, (McGraw-Hill Book Co).

Additional Resources

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

MA3D1 Fluid Dynamics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3d1)
Lecturer: James Sprittles

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour exam

Prerequisites: MA231 Vector Analysis and MA250 PDEs.
MA3B8 Complex Analysis is desirable.

Leads To:

Content: The lectures will provide a solid background in the mathematical description of fluid dynamics. They will cover the derivation of the conservation laws (mass, momentum,energy) that describe the dynamics of fluids and their application to a remarkable range of phenomena including water waves, sound propagation, atmospheric dynamics and aerodynamics. The focus will be on deriving approximate expressions using (usually) known mathematical techniques that yield analytic (as opposed to computational) solutions.

The module will cover the following topics:

- ***Mathematical modelling of fluid flow.*** Specification of the flow by field variables; vorticity; stream function; strain tensor; stress tensor. Euler's equation. Navier-Stokes equation. Introduction of non-dimensional parameters
- ***Additional conservation laws***. Bernoulli's equations. Global conservation laws.
- ***Vortex dynamics***. Kelvin's circulation theorem. Helmholtz theorems. Cauchy-Lagrange theorem. 3D vorticity equation, vortex lines, vortex tubes and vortex stretching.

- *2D flows*. Flow in a pipe. Shear flows. Jet flow by similarity solution. Round vortices.
- ***Irrotational 2D flows & classical aerofoil theory***. Complex analysis methods in Fluid Dynamics. Blasius theorem. Zhukovskii lift theorem. Force on a cylinder and force on an aerofoil.
- ***Rotating flows***. Navier-Stokes in a rotating frame. Rossby number. Taylor-Proudman theorem. Geophysical flow.
- ***Boundary layers.*** Prandtl's boundary layer theory. Ekman boundary layer in rotating fluids.
- ***Waves***. General theory of waves. Sound waves. Free-surface flows & surface tension. Gravity-capillary water waves.
- ***Instabilities.*** Rayleigh criterion. Orr-Sommerfeld equation. Kelvin-Helmholtz instability. Stability of parallel flows.

Aims:
An important aim of the module is to provide an appreciation of the complexities and beauty of fluid motion. This will be highlighted in class using videos of the phenomena under consideration (usually available on YouTube).

Objectives: It is expected that by the end of this module students will be able to:
- be able to understand the derivation of the equations of fluid dynamics
- master a range of mathematical techniques that enable the approximate solution to the aforementioned equations
- be able to interpret the meanings of these solutions in 'real life' problems

Strongly recommended texts:
D.J. Acheson, Elementary Fluid Dynamics, OUP. (Excellent text with derivations, examples and solutions)
S. Nazarenko, *Fluid Dynamics via Examples and Solutions*, Taylor and Francis. (Great source of questions and detailed solutions.)

Further Reading:
A.R. Paterson, *A First Course in Fluid Dynamics*, CUP. (Easier than Acheson.)
L.D. Landau and E.M. Livshitz, *Fluid Mechanics*, OUP. (A classic for those with a deep interest in fluid dynamics in modern physics.)
D.J. Tritton, Physical Fluid Dynamics , Oxford Science Publs. (The emphasis is on the physical phenomena and less on the mathematics.)

Additional Resources

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

Archived Material Before 2011

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3d1/pre-2011)

The following is selected material that used to be archived on the Department's previous bespoke module information website "MathStuff", published before the 2011/12 academic year (essentially old lecture notes and associated material but not assignment sheets). Please note that the syllabus to this module may have changed, and/or some topics may have been covered in previous years that are not done so now (or vice versa), so please only use for reference purposes.

Academic Year 2007/08

Complete Lecture Notes

Academic Year 2000/01

Lecture Notes 1
Lecture Notes 2
Lecture Notes 3
Lecture Notes 4
Lecture Notes 5
Lecture Notes 6
Lecture Notes 7
Lecture Notes 8
Lecture Notes 9
Lecture Notes 10
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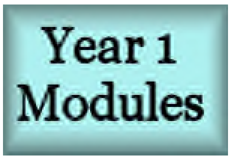
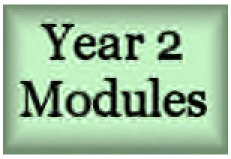
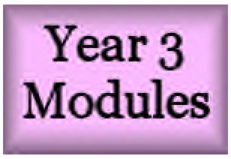
Lecture Notes 28



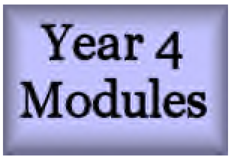
Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC

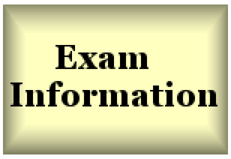


Year 3 regs and modules
G100 G103



Year 4 regs and modules

G103



Past Exams

Core module averages

MA3F2 Knot Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3f2)
Lecturer: Daan Krammer

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour exam

Prerequisites: MA3F1 Introduction to Topology

Leads To: MA408 Algebraic Topology and MA447 Homotopy Theory.

Content: A knot is a smooth embedded circle in R^3. After a geometric introduction of knots our approach is rather algebraic, heavily leaning on Reidemeister moves.

Prerequisites: Little more than linear algebra plus an ability to visualise objects in 3-dimensions. Some knowledge of groups given by generators and relations, and some basic topology would be helpful.

Books:

Listed in order of accessibility:

Colin C Adams, *The Knot Book*, W H Freeman, 1994.

Livingston, Charles. *Knot Theory* Washington, DC: Math. Assoc. Amer., 1993. 240 p.

N.D. Gilbert and T. Porter, *Knots and surfaces*, Oxford, Oxford University Press, 1994.

Peter Cromwell, *Knots and Links*, CUP, 2004.

Louis H. Kauffman, *Knots and physics*, Singapore, Teaneck, N.J., World Scientific, 1991 Series on knots and everything, v.1.

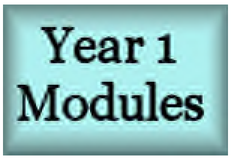
Louis H. Kauffman, *On knots*, Princeton, N.J., Princeton University Press, 1987 Annals of mathematics studies, 115.

Dale Rolfsen, *Knots and links*, Berkeley, CA, Publish or Perish, c1976 Mathematics lecture series, 7.

Gerhard Burde, Heiner Zieschang, *Knots*, Berlin, New York, W. De Gruyter, 1985 De Gruyter studies in mathematics, 5.

Lectures from previous years are available on the web.

Additional Resources



Year 1 regs and modules

G100 G103 GL11 G1NC

MA3G0 Modern Control Theory (now MA3H7)

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g0)

Please note that this module is now being taught as MA3H7

Status for Mathematics students: List A

Commitment: 30 one-hour lectures plus 8 example classes

Assessment: 3 hour examination

Prerequisites: MA106 Linear Algebra. , MA133 Differential Equations

Leads To:

Content: Will include the study of controllability, stabilization, observability, filtering and optimal control. Furthermore connections between these concepts will also be studied. Both linear and nonlinear systems will be considered. The module will comprise six chapters. The necessary background material in linear algebra, differential equations and probability will be developed as part of the course.

1. Introduction to Key Concepts.
2. Background Material.
3. Controllability.
4. Stabilization.
5. Observability and Filtering.
6. Optimal Control.

Aims: The aim of the module is to show how, as a result of extensive interests of mathematicians, control theory has developed from being a theoretical basis for control engineering into a versatile and active branch of applied mathematics.

Objectives: The objective is to ensure the aims are carried out by teaching the state space theory approach as outlined in the syllabus.

Books:

E. D. Sontag, *Mathematical Control Theory*, Texts in Applied Mathematics No 6, Springer Verlag, 1990.

J. Zabczyk, *Mathematical Control Theory: An Introduction*, Systems and Control, Birkhauser, 1992.

Additional Resources

MA3G1 Theory of Partial Differential Equations

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g1)
Lecturer: Julian Braun

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: Exam 100%

Prerequisites: This module uses material from many of the Core 1st and 2nd year modules, particularly MA231 Vector Analysis, MA244 Analysis III and MA250 Introduction to Partial Differential Equations. A student taking this module will benefit from having taken MA222 Metric Spaces but this not a formal prerequisite.

Leads To: MA4L3 Large Deviation theory

Content:
The important and pervasive role played by pdes in both pure and applied mathematics is described in MA250 Introduction to Partial Differential Equations. In this module I will introduce methods for solving (or at least establishing the existence of a solution!) various types of pdes. Unlike odes, the domain on which a pde is to be solved plays an important role. In the second year course MA250, most pdes were solved on domains with symmetry (eg round disk or square) by using special methods (like separation of variables) which are not applicable on general domains. You will see in this module the essential role that much of the analysis you have been taught in the first two years plays in the general theory of pdes. You will also see how advanced topics in analysis, such as MA3G7 Functional Analysis I, grew out of an abstract formulation of pdes. Topics in this module include:

- Method of characteristics for first order PDEs.
- Fundamental solution of Laplace equation, Green's function.
- Harmonic functions and their properties, including compactness and regularity.
- Comparison and maximum principles.

- The Gaussian heat kernel, diffusion equations.
- Basics of wave equation (time permitting).

Aims:
The aim of this course is to introduce students to general questions of existence, uniqueness and properties of solutions to partial differential equations.

Objectives:
Students who have successfully taken this module should be aware of several different types of pdes, have a knowledge of some of the methods that are used for discussing existence and uniqueness of solutions to the Dirichlet problem for the Laplacian, have a knowledge of properties of harmonic functions, have a rudimentary knowledge of solutions of parabolic and wave equations.

Books:
Fritz John, *Partial Differential Equations*, Springer, 1982.
L.C. Evans, *Partial Differential Equations*, American Mathematical Society, 1998.
E. Dibenedetto, *Partial Differential Equations*, Birkhauser, 2010.
D.Gilbarg - N.Trudinger, *Elliptic Partial Differential Equations of Second Order*, Springer, 2001 (more advanced, optional).

More detailed advice on books will be given during lectures.

Additional Resources

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

MA3G6 Commutative Algebra

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g6)
Lecturer: Chunyi Li

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one-hour lectures.

Assessment: 3 hour examination (85%), 15% coursework (15%)

Prerequisites: MA251 Algebra I: Advanced Linear Algebra and MA249 Algebra II

Leads To and/or related to: MA3A6 Algebraic Number Theory, MA4A5 Algebraic Geometry, MA377 Rings and Modules (which concentrates more on non-commutative theory), MA3D5 Galois Theory.

Content:
Commutative Algebra is the study of commutative rings, and their modules and ideals. This theory has developed over the last 150 years not just as an area of algebra considered for its own sake, but as a tool in the study of two enormously important branches of mathematics: algebraic geometry and algebraic number theory. The unification which results, where the same underlying algebraic structures arise both in geometry and in number theory, has been one of the crowning glories of twentieth century mathematics and still plays an absolutely fundamental role in current work in both these fields.

One simple example of this unification will be familiar already to anyone who has noticed the strong parallels between the ring Z (a Euclidean Domain and hence also a Unique Factorization Domain) and the ring F[X] of polynomials over a field (which has both the same properties). More generally, the rings of algebraic integers which have been studied since the 19th century to solve problems in number theory have parallels in rings of functions on curves in geometry.

While self-contained, this course will also serve as a useful introduction to either algebraic geometry or algebraic number theory.

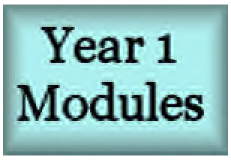
Topics: Gröbner bases, modules, localization, integral closure, primary decomposition, valuations and dimension.

Objectives:
This course will give the student a solid grounding in commutative algebra which is used in both algebraic geometry and number theory.

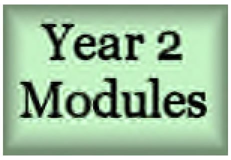
Books:
Recommended texts:

M.F. Atiyah, I.G. MacDonald, *Introduction to Commutative Algebra*. Addison-Wesley 1969; reprinted by Perseus 2000. [QA251.3.A8]
D. Eisenbud, Commutative algebra with a view toward algebraic geometry. Springer 1995. [QA251.3.E4]
M. Reid, *Undergraduate Commutative Algebra*. CUP 1995. [QA251.3.R3]
R.Y. Sharp, *Steps in Commutative Algebra* (2nd ed.) CUP 2000. [QA251.3.S4]
O. Zariski and P. Samuel, *Commutative Algebra*, (vols I and II). Springer 1975-6. [QA251.3.Z2]

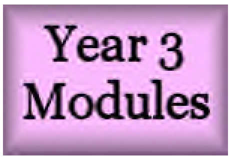
Additional Resources



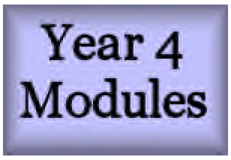
Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

MA3G6 Forum 2016

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g6/forum2016)

Search this forum

MA3G6 Forum 2016

20 followers

1. Revision lecture rescheduled

   6 posts, started by Diane Maclagan, 10:29, Wed 11 May 2016, latest post by Callum Sturgiss, 13:09, Tue 17 May 2016
2. Primary decomposition

   3 posts, started by Ami Patel, 09:25, Sun 15 May 2016, latest post by Diane Maclagan, 17:09, Sun 15 May 2016
3. Solutions to any questions

   9 posts, started by Michael Beech, 08:41, Wed 11 May 2016, latest post by Diane Maclagan, 17:05, Sun 15 May 2016
4. Cayley Hamilton Proof I

   2 posts, started by Oli Lynch, 13:26, Fri 13 May 2016, latest post by Diane Maclagan, 13:39, Fri 13 May 2016
5. Results in assignments not covered in lectures

   2 posts, started by Reema Sodha, 21:08, Wed 11 May 2016, latest post by Diane Maclagan, 22:36, Wed 11 May 2016
6. Assignment 3 q 6 b

   2 posts, started by Rowan Swiers, 14:45, Mon 9 May 2016, latest post by Diane Maclagan, 15:24, Mon 9 May 2016
7. Lemma on R[U^-1]

   2 posts, started by Michael Beech, 12:09, Mon 9 May 2016, latest post by Diane Maclagan, 15:20, Mon 9 May 2016
8. Emailed question about the exam

   1 post, started by Diane Maclagan, 10:19, Sun 8 May 2016
9. Commutative Assumption

   3 posts, started by Oli Lynch, 12:56, Fri 6 May 2016, latest post by Diane Maclagan, 10:10, Sun 8 May 2016
10. Proof of Cayley Hamilton

    2 posts, started by Fred Bisson, 10:02, Thu 5 May 2016, latest post by Diane Maclagan, 10:09, Sun 8 May 2016
11. Products of ideals

    1 post, started by Diane Maclagan, 01:13, Mon 2 May 2016
12. Typo in Primary Decomposition hand-out?

    2 posts, started by Tom Hanna, 18:18, Tue 29 Mar 2016, latest post by Diane Maclagan, 22:24, Tue 29 Mar 2016
13. Conventions about notation

    1 post, started by Diane Maclagan, 18:52, Fri 25 Mar 2016
14. HW5

2 posts, started by Osian Shelley, 21:39, Tue 15 Mar 2016, latest post by Diane Maclagan, 22:36, Wed 16 Mar 2016

15. HW sheet 5

    2 posts, started by Ami Patel, 20:27, Tue 15 Mar 2016, latest post by Diane Maclagan, 22:30, Wed 16 Mar 2016

16. Confusion on Q6 and Q7

    6 posts, started by Michael Beech, 15:18, Mon 14 Mar 2016, latest post by Diane Maclagan, 10:52, Tue 15 Mar 2016

17. QB2 of HW5

    4 posts, started by Reema Sodha, 10:21, Sun 13 Mar 2016, latest post by Diane Maclagan, 20:21, Sun 13 Mar 2016

18. HW4 Q5

    4 posts, started by Jack Cawdron, 11:27, Mon 7 Mar 2016, latest post by Diane Maclagan, 04:04, Tue 8 Mar 2016

19. HW4 Q1

    7 posts, started by Michael Beech, 16:58, Tue 1 Mar 2016, latest post by Diane Maclagan, 04:03, Tue 8 Mar 2016

20. HW4 QB5

    7 posts, started by Reema Sodha, 12:41, Sun 28 Feb 2016, latest post by Diane Maclagan, 22:56, Thu 3 Mar 2016

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MA3G6 Forum 2017

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g6/forum2017)

Search this forum

MA3G6 Forum 2017

36 followers

1. Revision questions

   41 posts, started by Diane Maclagan, 16:20, Sat 6 May 2017, latest post by Dixy Msapato, 23:12, Tue 16 May 2017

2. Support class week 6 question

   10 posts, started by Matt Raymond, 14:32, Sun 14 May 2017, latest post by Ben Fripp, 18:26, Mon 15 May 2017

3. Revision Lecture Mon 8 May 12-2pm in L5 Sciences.

   4 posts, started by Vladimir Eremichev, 13:38, Fri 5 May 2017, latest post by Bruno Sterner, 17:29, Wed 10 May 2017

4. Notes Sharing Thread

   6 posts, started by Ben Swannack, 17:43, Fri 17 Mar 2017, latest post by Henry Dai, 10:12, Tue 9 May 2017

5. Support Class Exercises

   8 posts, started by Vladimir Eremichev, 13:07, Wed 8 Mar 2017, latest post by Vladimir Eremichev, 10:06, Tue 4 Apr 2017

6. Monday's Lecture Week 10

2 posts, started by Bruno Sterner, 12:12, Mon 13 Mar 2017, latest post by Diane Maclagan, 12:19, Mon 13 Mar 2017

7. Extra Supervision in Week 10

   1 post, started by Vladimir Eremichev, 14:56, Thu 9 Mar 2017

8. Sheet 5 'generated by some of the variables' terminology

   3 posts, started by Ben Windsor, 16:14, Wed 8 Mar 2017, latest post by Ben Windsor, 08:46, Thu 9 Mar 2017

9. Sheet 5 Topic Coverage

   2 posts, started by David Brown, 22:48, Tue 7 Mar 2017, latest post by Diane Maclagan, 09:43, Wed 8 Mar 2017

10. Sheet 5 Section B Question 3

    2 posts, started by William Fowler, 19:01, Tue 7 Mar 2017, latest post by Diane Maclagan, 20:56, Tue 7 Mar 2017

11. Sheet 4, Q4

    2 posts, started by Henry Dai, 19:30, Sat 4 Mar 2017, latest post by Diane Maclagan, 11:27, Sun 5 Mar 2017

12. Sheet 4, Q2

    6 posts, started by Henry Dai, 20:26, Mon 27 Feb 2017, latest post by Diane Maclagan, 11:22, Fri 3 Mar 2017

13. Assignment Solutions

    2 posts, started by Jelena Starovic, 10:26, Wed 22 Feb 2017, latest post by Diane Maclagan, 12:06, Wed 22 Feb 2017

14. HW3 Queries

    13 posts, started by Diane Maclagan, 09:14, Mon 13 Feb 2017, latest post by Diane Maclagan, 07:33, Sun 19 Feb 2017

15. Handout Query

    3 posts, started by William Fowler, 19:14, Fri 10 Feb 2017, latest post by Diane Maclagan, 08:59, Mon 13 Feb 2017

16. Problems with online version of Macaulay 2

    1 post, started by Diane Maclagan, 06:35, Tue 7 Feb 2017

17. Sheet 2 Question B5 ⊘

    2 posts, started by Henry Dai, 18:21, Sat 4 Feb 2017, latest post by Henry Dai, 18:26, Sat 4 Feb 2017

18. HW2 Q2

    1 post, started by Diane Maclagan, 15:31, Sat 4 Feb 2017

19. Sheet 2, Question 3

    2 posts, started by Henry Dai, 16:19, Fri 3 Feb 2017, latest post by Diane Maclagan, 18:28, Fri 3 Feb 2017

20. Sheet 2, Section B, Q3

    3 posts, started by William Fowler, 15:03, Wed 25 Jan 2017, latest post by William Fowler, 18:18, Wed 25 Jan 2017

- 1
- All

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3g8)
Lecturer: James Robinson

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour examination (100%)

Prerequisites: MA3G7 Functional Analysis I, MA359 Measure Theory would be useful but is not required

Leads To: MA4A2 Advanced PDEs, MA433 Fourier Analysis, MA4G6 Calculus of Variations, MA4A2 Advanced PDEs
and MA4J0 Advanced Real Analysis.

Content: Problems posed in infinite-dimensional space arise very naturally throughout mathematics, both pure and applied. In this module we will concentrate on the fundamental results in the theory of infinite-dimensional Banach spaces (complete normed linear spaces) and linear transformations between such spaces.

We will prove some of the main theorems about such linear spaces and their dual spaces (the space of all bounded linear functionals) - e.g.
the Hahn-Banach Theorem and the Principle of Uniform Boundedness - and show that even though the unit ball is not compact in an infinite-dimensional space, the notion of weak convergence provides a way to overcome this.

In the final part of the course we will study the theory of distributions ("generalised functions") which allows one to make rigorous sense of the Dirac delta "function" and is a fundamental part of the modern theory of partial differential equations.

Books: Useful books to use as an accompanying reference to your lecture notes are:

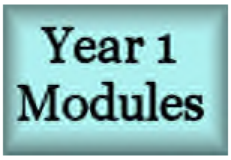
E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley, 1989.

W. Rudin, *Functional Analysis*, McGraw-Hill, 1973.

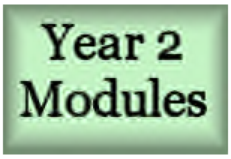
G. B. Folland, *Real Analysis*, Wiley, 1999.

E.H. Lieb and M. Loss, *Analysis*, 2nd ed. American Mathematical Society, 2001.

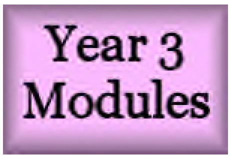
Additional Resources



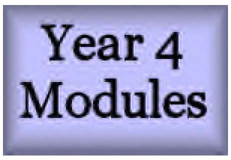
Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103

Exam Information

Past Exams

Core module averages

MA3H0 Numerical Analysis and PDE's

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h0)
Lecturer: Björn Stinner

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour exam 100%

Prerequisites: This module uses material from many of the Core 1st and 2nd year modules, particularly MA231 Vector Analysis, MA244 Analysis III and MA250 Introduction to PDE. Although not prerequisites MA3G7 *Functional analysis Functional Analysis I* and MA3G1 *Theory of PDEs* are excellent companion courses.

Leads To:

Content:
This module addresses the mathematical theory of discretization of partial differential equations (PDEs) which is one of the most important aspects of modern applied mathematics. Because of the ubiquitous nature of PDE based mathematical models in biology, finance, physics, advanced materials and engineering much of mathematical analysis is devoted to their study. The complexity of the models means that finding formulae for solutions is impossible in most practical situations. This leads to the subject of computational PDEs. On the other hand, the understanding of numerical solution requires advanced mathematical analysis. A paradigm for modern applied mathematics is the synergy between analysis, modelling and computation. This course is an introduction to the numerical analysis of PDEs which is designed to emphasise the interaction between mathematical theory and numerical methods.

Topics in this module include:
Analysis and numerical analysis of two point boundary value problems.
Model finite difference methods and and their analysis.
Variational formulation of elliptic PDEs; function spaces; Galerkin method; finite element method; examples of finite elements; error analysis.

Aims:
The aim of this module is to provide an introduction to the analysis and design of numerical methods for solving partial differential equations of elliptic, hyperbolic and parabolic type.

Objectives:
Students who have successfully taken this module should be aware of the issues around the discretization of several different types of pdes, have a knowledge of the finite element and finite difference methods that are used for discretizing, be able to discretise an elliptic partial differential equation using finite element and finite difference methods, carry out stability and error analysis for the discrete approximation to elliptic, parabolic and hyperbolic equations in certain domains.

Books:
Background reading:

Stig Larsson and Vidar Thomee, *Partial differential equations with numerical methods*, Springer Texts in Applied Mathematics Volume 45 (2005).
K W Morton and D F Mayers, *Numerical solution of partial differential equations: an introduction* Cambridge University Press Second edition (2005).

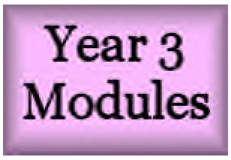
Additional Resources

Year 1 Modules

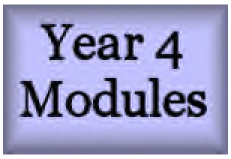
Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

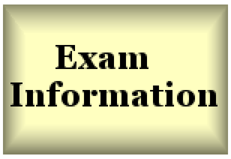
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA3H2 Markov Processes and Percolation Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h2)
Lecturer: Roman Kotecký
Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 3 hour exam 85%, assignments 15%

Prerequisites: As a prerequisite module students should have done MA359 Measure Theory or one of the following modules, MA253 Probability and Discrete Mathematics or ST213 Mathematics of random events. Alternatively, the students need to know the following basic key facts: probability measure , expectation and variance, law of large numbers, and Probability A module [as Probability A is a core module there are no further compulsory prerequisites].

Leads To: MA482 Stochastic Analysis,MA4F7 Brownian Motion, and MA4H3 Interacting Particle Systems, ST406 Applied Stochastic Processes with Advanced Topics, CO905 Stochastic models of complex systems and MA4L3 Large Deviation theory.

Content: This module provides an introduction to continuous-time Markov processes and percolation theory, which have numerous applications: random growth models (sand-pile models), Markov decision processes, communication networks.

The module first introduces the theory of Markov processes with continuous time parameter running on graphs. An example of a graph is the two-dimensional integer lattice and an example of a Markov process is a random walk on this lattice. Very interesting problems of such processes involve spatial disorder and dependencies (e.g. burning forests). Therefore, after the main part, an elementary introduction to percolation theory will be given which can be used to study such questions.

Percolation is a simple probabilistic model for spatial disorder, and in physics, chemistry and materials science, percolation concerns the movement and filtering of fluids through porous materials. Recent applications include for example percolation of water through ice which is important for the melting of the ice caps.

Let us briefly explain the mathematical setting. Percolation is a simple probabilistic model which exhibits a phase transition. The simplest version of percolation takes place on $\mathbb{Z}^2$, which we view as a graph with edges between neighbouring vertices. All edges of $\mathbb{Z}^2$ are, independently of each other, chosen to be open with probability p and closed with probability $1-p$. A basic question in this model is `What is the probability that there exists an open path from the origin to the exterior of the square $S_n = [-n, n]^2$?' A limit as $n \to \infty$ of the question raised above is `What is the probability that there exists an open path from 0 to infinity?' This probability is called the percolation probability and is denoted by $\theta(p)$. Clearly $\theta(0) = 0$ and $\theta(1) = 1$, since there are no open edges at all when $p = 0$ and all edges are open when $p = 1$. For some models there is a $0 < p_c < 1$ such that the global behaviour of the system is quite different for $p < p_c$ and for $p > p_c$. Such a sharp transition in global behaviour of a system at some parameter value is called a phase transition or a critical phenomenon, and the parameter value at which the transition takes place is called a critical value.

The basic mathematical methods and techniques of random processes and an overview of the most important applications will enable the student to use analytical techniques and models to study questions in modern applications in biological and physical systems, communication networks, financial market, decision processes.

Books:

We will not follow a particular book.

H.O. Georgii: *Stochastics: introduction to probability theory and statistics*, de Gruyter (2008). [basic introduction to stochastics and Markov chains (discrete time)]

J. Norris: *Markov chains*, Cambridge University Press [standard reference treating the topic with mathematical rigor and clarity, and emphasizing numerous applications to a wide range of subjects]

G. Grimmett, D. Stirzaker: *Probability and Random Processes*, OUP Oxford (2001) [chapter 6 on Markov chains]

G. Grimmett: *Probability on Graphs*, Cambridge University Press (2010). [Available Online, contains a nice introduction to processes on graphs and percolation]

B. Bollabás, O. Riordan: *Percolation*, Cambridge University Press (2006). [a modern treatment of percolation. The introduction and the chapter on basic techniques are relevant for the lecture]

G. Grimmett: *Percolation*, 2nd ed., Springer (1999). [the standard reference on percolation. It contains much more than covered in the lecture. The first two chapters are relevant for the lecture]

Additional Resources

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
G100 G103 GL11 G1NC

Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

MA3H6 Algebraic Topology

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h6)
Lecturer: David Mond

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 hours

Assessment: 3 hour examination (85%), assessed work (15%)

Prerequisites: MA3F1 Introduction to Topology

Prerequisite for: MA4J7 Cohomology and Poincaré Duality

Leads To: MA4A5 Algebraic Geometry, MA5Q6 Graduate Algebra

Content: Algebraic topology is concerned with the construction of algebraic invariants (usually groups) associated to topological spaces which serve to distinguish between them. Most of these invariants are ``homotopy'' invariants. In essence, this means that they do not change under continuous deformation of the space and homotopy is a precise way of formulating the idea of continuous deformation. This module will concentrate on constructing the most basic family of such invariants, *homology groups*, and the applications of these homology groups.

The starting point will be *simplicial complexes* and *simplicial homology*. An *n-simplex* is the n-dimensional generalisation of a triangle in the plane. A simplicial complex is a topological space which can be decomposed as a union of simplices. The simplicial homology depends on the way these simplices fit together to form the given space. Roughly speaking, it measures the number of p-dimensional "holes'' in the simplicial complex. For example, a hollow 2-sphere has one 2-dimensional hole, and no 1-dimensional holes. A hollow torus has one 2-dimensional hole and two 1-dimensional holes. Singular homology is the generalisation of simplicial homology to arbitrary topological spaces. The key idea is to replace a simplex in a simplicial complex by a continuous map from a standard simplex into the topological space. It is not that hard to prove that singular homology is a homotopy invariant but very hard to compute singular homology directly from the definition. One of the main results in the module will be the proof that simplicial homology and singular homology agree for simplicial complexes. This result means that we can combine the theoretical power of singular homology and the computability of simplicial homology to get many applications. These applications will include the Brouwer fixed point theorem, the Lefschetz fixed point theorem and applications to the study of vector fields on spheres.

Aims: To introduce homology groups for simplicial complexes; to extend these to the singular homology groups of topological spaces; to prove the topological and homotopy invariance of homology; to give applications to some classical topological problems.

Objectives: By the end of the module the student should be able to:

Give the definitions of simplicial complexes and their homology groups and a geometric understanding of what these groups measure
Use standard techniques for computing these groups
Give the extension to singular homology
Understand the theoretical power of singular homology
Develop a geometric understanding of how to use these groups in practice

Text:
The course is based on chapter 2 of Allen Hatcher's book:
Algebraic Topology, CUP. (Available free from Hatcher's website).

Strongly recommended preliminary reading
Ideal for the summer holidays, and a good preparation also for MA3F1 Introduction to Topology:
David Richeson, *Euler's Gem*, Princeton, 2008
Jeffrey Weeks, *The Shape of Space*, Marcel Dekker, 2001

Additional references:
JW Vick, *Homology Theory: an introduction to algebraic topology*, Academic Press.
MA Armstrong, *Basic Topology*, Undergraduate Texts in Mathematics, Springer Verlag
Maunder, *Algebraic Topology*, Cambridge University Press.
A Dold, *Lectures on Algebraic Topology*, Springer-Verlag.

Additional Resources

Year 1 regs and modules
G100 G103 GL11 G1NC

MA3H8 Equivariant Bifurcation Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/ma3h8)

Not Running 2016/17

Lecturer: David Wood

Term(s): Term 1

Status for Mathematics students: List A

Commitment: 30 hours

Assessment: 3 hour examination (100%)

Prerequisites: MA133 Differential Equations, aspects of MA249 Algebra II and MA225 Differentiation, MA254 Theory of ODEs useful but not essential

Content: Equivariant Bifurcation Theory is the study of systems of equations which have an inherent symmetry within them, it is a perfect fusion of pure and applied mathematics, leading to some quite powerful and aesthetically pleasing results. The module will concentrate primarily on systems of ordinary differential equations, and both steady-state and periodic solutions that are formed through bifurcations as a parameter is varied, but the theory can also be applied to discrete systems and systems of partial differential equations.

Essential background required includes solving systems of first order differential equations from Differential Equations, and knowledge of symmetry groups from Algebra II: in particular we concentrate on those that have physical symmetry interpretations such as permutation groups (S_n), symmetries of regular n-gons (D_n) and circle group symmetries ($O(2)$ and $SO(2)$). Additional knowledge from the second year Theory of ODEs or third year Qualitative Theory of ODEs will help but not having taken neither should not prove a major obstacle.

The module should appeal to both students who wish to study applications of mathematics, and those who enjoy the beauty of mathematics for its own sake.

In more detail the topics to be covered will include:

0. **Overview:** Basic bifurcation theory (standard one parameter bifurcations) and symmetry groups (essentially revision).

1. **Steady-State Bifurcation:** Symmetries of ODEs, Liapunov Schmidt reduction, Equivariant Branching Lemma, applications (inc. coupled cell networks and speciation).

2. **Linear Stability:** Symmetry of the Jacobian, Hilbert Bases and Equivariant Mappings, examples of Dn Steady State Bifurcations and Sn Invariant Theory.

3. **Time Periocicity and Spatio-Temporal Symmetry**: Animal gaits, characterization of possible spatio-temporal symmetries, rings of cells, coupled cell networks.

4. **Hopf Bifurcation with Symmetry:** linear analysis, the Equivariant Hopf Theorem, Poincaré-Birkhoff Normal Form, Hopf Bifurcation in Coupled Cell Networks (esp Dn), mode interactions.

Further topics from (depending on time and interest): Forced symmetry breaking, Euclidean Equivariant systems (example of liquid crystals), bifurcation from group orbits (Taylor Couette), heteroclinic cycles, symmetric chaos, Reaction-Diffusion equations, hidden symmetries, networks of cells (groupoid formalism).

Aims:

Objectives:

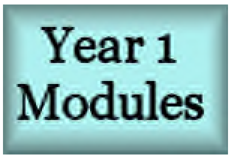
Books: Printed lecture notes will be made available as the module progresses, but other good textbooks for reference:

The Symmetry Perspective, Golubitsky and Stewart, 2002
Singularities and Groups in Bifurcation Theory Vol 2, Golubitsky/Stewart/Schaeffer 1988
Pattern Formation, Hoyle 2006.

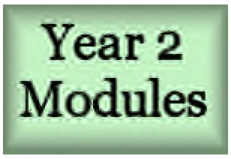
For more general background of relevant ODE theory:

Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields, Guckenheimer/Holmes 1983

Additional Resources



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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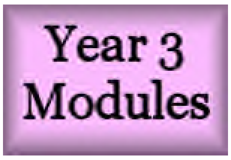
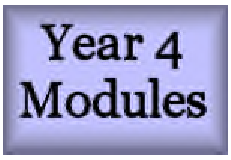
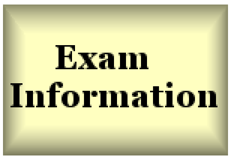


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

ST218: Mathematical Statistics Part A

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st218)
Lecturer(s)

Dr Zorana Lazic

Important: This module is for students from the Statistics department only. Students from other departments should take ST220 Introduction to Mathematical Statistics.

Prerequisite(s): ST115 Introduction to Probability.

Commitment: 3 lectures/week, 1 tutorial/fortnight. This module runs in Term 1.

Aims: To build the necessary probability background for mathematical statistics.

Content:

1. Discrete and continuous multivariate distributions. Marginal distributions.
2. Jacobian transformation formula.
3. Conditional distributions, conditional expectation and properties.
4. Moment generating functions for multivariate random variables.
5. Multivariate Gaussian distribution and properties.
6. Distributions related to Gaussian distribution: the Chi-squared, Student's and Fisher distributions.
7. Convergence in distribution, convergence in probability and almost sure convergence. Examples.
8. Laws of large numbers.
9. Central limit theorem.

Books:

A.Gut: An Intermediate Course in Probability

Casella and Berger: Statistical Inference

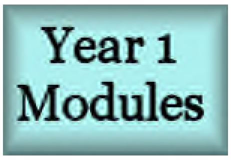
Suhov and Kelbert: Probability and Statistics by Example: Basic Probability and Statistics

J.Pitman: Probability

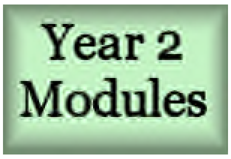
Assessment: 90% by 2 hour examination in January, 10% by coursework.

Deadline: Assignment 1: week 3, Assignment 2: week 5, Assignment 3: week 7 and Assignment 4: week 9.

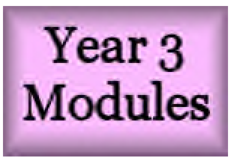
Feedback: You will hand in answers to selected questions on the fortnightly exercise sheets. Your work will be marked and returned to you in the tutorial taking place the following week when you will have the opportunity to discuss it. The results of the January examination will be available in week 10 of term 2.



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103

ST301 Bayesian Statistics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st301)
Lecturer(s)

Dr Ric Crossman

Important: If you decide to take ST301 you cannot then take ST413. Bear this in mind when planning your module selection. Recall: an integrated Masters student must take at least 120 CATS, of level 4+ modules over their 3rd & 4th years.

Prerequisite(s): Either ST218/219 Mathematical Statistics A&B or ST220 Introduction to Mathematical Statistics

Commitment: 3 lectures per week. This module runs in Term 1.

Content: Bayesian statistics is one of the fastest growing areas in statistics. With the advance of computer technology it is now a highly practical methodology for addressing many important high dimensional decision problems as well as being underpinned by a sound mathematical foundation. It is especially useful when some of the components of uncertainty have only sparsely collected data associated with them, so that expert judgements need to be incorporated. The course first introduces the central concepts of Bayesian decision analysis through a selection of simple examples. Various methodologies are then presented for:

- Structuring a decision problem – for example by decision trees and influence diagrams.
- Eliciting probability distributions over many variables – using the concepts of irrelevance and the Belief net.
- Eliciting the objectives and preferences of the client – developing the ideas of m.u.i.a. and value independence and the use of the decision conference.

The formal methodologies are illustrated through a wide range of examples for health, the environment, finance and public sector administration. Some of the examples build on the practical experience of the module's original creator as an active Bayesian decision analyst.

Aims:

- To demonstrate how to build statistical models of non-trivial problems when data is sparse and expert judgements need to be incorporated.
- To give ways to represent the pertinent features of a decision problem.
- To give practical algorithms for finding decision rules which the client can expect will best satisfy pre-specified objectives.
- To train the student in the rudiments of decision analysis.

Objectives:

- The student will gain an appreciation of the importance of conditional independence in subjective (Bayesian) statistical modelling and be introduced to the DAG as an efficient representation of collections of conditional independence statements as they arise in practice.
- The student will be provided with techniques for eliciting subjective probability distributions over many variables.
- The student will be provided with techniques for eliciting quantitative preference structures from a client which may involve competing objectives.
- The student will obtain an appreciation of the foundational arguments that justify expected utility maximisation as a paradigm for rational action.
- The student will obtain practice in implementing these techniques.
- The student will learn the bases of fast algorithms for the calculation of probabilities needed in such maximisation.

Assessment: 100% by 2-hour examination.

ST305 Designed Experiments

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st305)

Lecturer(s)

Dr John Fenlon

Important: If you decide to take ST305 you cannot then take ST410. Bear this in mind when planning your module selection. Recall: an Integrated Masters student must take at least 120 CATS, of level 4+ modules over their 3rd & 4th years.

Prerequisite(s): Either ST218/219 Mathematical Statistics A&B or ST220 Introduction to Mathematical Statistics

Commitment: 30 one-hour lectures, plus weekly one-hour seminars / practicals. This module runs in Term 2.

Background: Designed experiments are used in industry, agriculture, medicine and many other areas of activity to test hypotheses, to learn about processes and to predict future responses. The primary purpose of experimentation is to determine the relationship between a response variable and the settings of a number of experimental variables (or factors) that are presumed to affect it. Experimental design is the discipline of determining the number and order (spatial or temporal) of experimental runs, and the setting of the experimental variables.

Content: This is a first course in designed experiments. The elementary theory of experimental design relies on linear models, while the practice involves important eliciting and communication skills. In this course we shall see how the theory links common designs such as the randomised complete block and split-plot to the underlying model. The course will commence with a review of linear model theory and some simple designs; we shall then examine the basic principles of experimental design and analysis, e.g. the concepts of randomisation and replication together with the blocking in designs and the combination of experimental treatments (factorial structure). Classical design structures are developed through the separate consideration of block and treatment structure, and the use of analysis of variance to explore differences between treatments for different types of design is explored. Throughout, diagnostic and analysis methods for the examination of practical experiments will be developed. A significant part of the course will be spent developing aspects of factorial design theory, including the theory and practice of confounding and of fractional designs. We will see how the exigencies of design in an industrial context have led to further theory and different emphases from classical design. This will include the use of regression in response surface modelling. Further topics such as repeated measures, non-linear design and optimal design theory may be included if time allows. Practical examples from many different application areas will be given throughout, with an emphasis on analysis using R.

Aims: This course aims to give students a sound understanding of experimental design, both theoretical and practical. The course will explore the method of analysis of variance and show how it is structurally linked to particular types of design. The combinatoric properties of designs will be explored, and the impact of computers on classical design considered. Some exploration of the matrix theory of design will also be undertaken.

Objectives: By the end of the course students will be able to:

• Describe the basic principles behind designed experiments

• Show the relationship between a designed experiment, the underlying linear model and the analysis of the resulting data

• Construct the design matrix for a simple experiment and estimate the model parameters

• Perform an analysis of variance on standard experimental designs

• Distinguish between different types of design and recognise their efficiency / utility

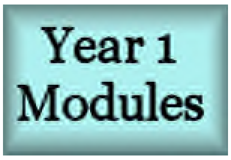
• Perform diagnostic tests on the results from a designed experiment.

• Explain the underlying theory of 2"/3" factorial designs, and implement such designs in practice.

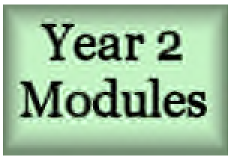
Books: G Clarke & R Kempson, Introduction to the Design and Analysis of Experiments, Arnold, 1996. DC Montgomery, Design and Analysis of Experiments, Wiley, 2005, 2009, 2012. Other books will be referred to through the module.

Assessment: 9% by assignment 1, 11% by assignment 2 and 80% by 2-hour examination. Assignment 1 will be submitted at approx. half-way through the course and assignment 2 at the end. Other exercises will be provided and discussed during the seminars.

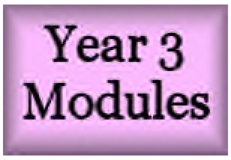
Feedback: Feedback on both assignment 1 and 2 will be returned after 2 weeks, following submission. Students will also receive feedback to worksheet examples during practical classes.



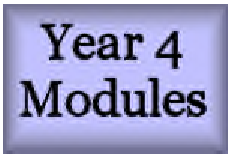
Year 1 regs and modules
G100 G103 GL11 G1NC



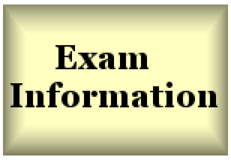
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

ST323: Multivariate Statistics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year3/st323)
Lecturer(s)

Dr Shahin Tavakoli

Important: If you decide to take ST323 you cannot then take ST412. Bear this in mind when planning your module selection. Recall: an integrated Masters student must take at least 120 CATS, of level 4+ modules over their 3^{rd} & 4^{th} years.

Prerequisite(s): ST208 Mathematical Methods or equivalent, either ST218/219 Mathematical Statistics A&B or ST220 Introduction to Mathematical Statistics