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Course Regulations for Year 2

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2)

To create a printable version of this section of the Handbook click on the "pages to go" link at the bottom right.

Please note: students entering the University from October 2017 onwards will be studying a refreshed second year curriculum where the essential core material has been included in fewer core modules with less overlap. More information can be found HERE.

MATHEMATICS BSC. G100

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

Students must take the 6 core modules (total 66 CATS), plus options. List A modules have a high mathematical content. The Core modules are: MA231 Vector Analysis, MA244 Analysis III, MA251 Algebra I, MA249 Algebra II, MA225 Differentiation, MA213 Second Year Essay.

MASTER OF MATHEMATICS MMATH G103

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

The first two years are in common with the BSc Mathematics degree course G100 except that in Year 2 students must take the six core modules and must take either MA222 Metric Spaces or MA250 PDE (or both). In addition students must take at least 90 CATS credits from the core and List A combined.

To remain on the G103 course at the second year exam board students must have achieved a weighted average on their best 90 CATS of maths modules (Core and List A modules starting with an MA2 code) of a good 2.1 standard. The department strictly interprets this to mean 65.0% or above (if a student has less than 90 CATS of such modules the average os taken over the number of such CATS they have been examined for). Experience has shown that students who do not achieve this threshold struggle with the four year degree, and by being transferred to the BSc. have a better chance of achieving a good 2.1 or first class degree and can plan their future better.

Please note:4th year MMath students are not be able to take second year modules except as unusual options. It is highly unlikely that MA2 modules would be allowed as unusual so choose your modules this year to take this into account.

MATHEMATICS AND BUSINESS STUDIES G1NC

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

Students must take the 6 core modules for G100 students (total 66 CATS), plus one of the List B Warwick Business School modules below (coded IBxxx). To transfer to the Business School at the end of the second year students must get at least 50% in one of these modules, gain an overall honours mark (40% Seymour) and be successfully interviewed by WBS.

MATHEMATICS AND ECONOMICS GL11

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

Year 2 core consists of 60 CATS of Mathematics and 60 CATS of Economics. The Economics modules are EC204 Economics 2 (30 CATS), plus either EC226 Econometrics 1 (30 CATS) or EC220/221 Mathematical Economics 1a and 1b (30 CATS). The Mathematics modules are MA251 Algebra I, MA244 Analysis III, MA222 Metric Spaces and MA225 Differentiation, plus 12 CATS from option list A for the second year of the Mathematics BSc (G100). Students taking EC226 as a core module should consider, as recommended options, ST202 Stochastic Processes and/or ST213 Mathematics of Random Events. Students taking EC220/1 as a core module should consider MA209 Variational Principles.

Note, in year 3 GL11 students transfer to the Economics department where overcatting is not permitted and level 1 modules are also not allowed as options.

MATHEMATICS AND PHILOSOPHY GV17

Second year Mathematics and Philosophy students have transferred to the Philosophy Department and should consult their web pages regarding regulations and options.

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

Maths Modules

Note: The Term 1 modules MA231 Vector Analysis, MA241 Combinatorics, MA243 Geometry, MA244 Analysis III and MA251 Algebra I are all examined in the April exam period directly after the Easter vacation.

hide

Term	Code	Module	CATS	List GL11	List Others
Term 1	MA231	Vector Analysis	12	List A	Core
	MA241	Combinatorics	12	List A	List A
	MA243	Geometry	12	List A	List A
	MA244	Analysis III	12	Core	Core
	MA251	Algebra I: Advanced Linear Algebra	12	Core	Core
Terms 1 & 2	MA213	Second Year Essay	6	List A	Core
	MA250	Introduction to Partial Differential Equations (weeks 6 to 10, 15 to 19)	12	List A	List A
Term 2	MA117	Programming for Scientists	12	List B	List B
	MA222	Metric Spaces	12	Core	List A
	MA225	Differentiation	12	Core	Core
	MA228	Numerical Analysis (wks 15-19)	6	List A	List A
	MA249	Algebra II: Groups and Rings	12	List A	Core
	MA252	Combinatorial Optimization	12	List A	List A
	MA254	Theory of ODEs	12	List A	List A
	MA257	Introduction to Number Theory	12	List A	List A
Term 3	MA209	Variational Principles	6	List A	List A
	MA256	Introduction to Systems Biology	6	List A	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

Students who have successfully completed the first year in Maths and have taken statistics options in their first year may apply to the Department of Statistics for transfer to the joint degree. Alternatively, transfer may be made at the beginning of the third year if the appropriate second year modules have been taken. Further information may be obtained from the Department of Statistics.

hide

Term	Code	Module	CATS	List
Term 1	ST222	Games, Decisions and Behaviour	12	List A
	ST220	Introduction to Mathematical Statistics	12	List A

Term 2	ST202	Stochastic Processes	12	List A

Economics Modules

The Economics 2nd and 3rd Year Handbook is available on request from the Economics Department and contains details of their modules and prerequisites, including information on which will actually run during . This information is also available from the Economics web pages.

See the Economics Handbooks for information on the Joint degree in Mathematics and Economics.

Once you have consulted the Economics handbook, Dr Cave in Economics should be consulted if you have questions about the joint degree, or about economics options for the maths degrees.

hide

Term	Code	Module	CATS	List GL11	List Others
Term 1	EC220	Mathematical Economics 1A	15	Op Core	List B
Term 2	EC221	Mathematical Economics 1B	15	Op Core	List B
Terms 1,2,3	EC204	Economics 2	30	Core	N/A
	EC226	Econometrics 1	30	Op Core	N/A

Computer Science

hide

Term	Code	Module	CATS	List
Term 1	CS260	Algorithms	15	List B
Term 2	CS262	Logic and Verification	15	List B
	CS254	Algorithmic Graph Theory	15	List B

Physics

Students from the Department of Mathematics may take any combination of the modules listed below. All exams are one hour per 6 CATS. Julie Staunton (Room PS132) will be glad to answer any queries concerning the second year Physics modules.

Module Seminars for Physics Options: Certain physics modules are supported by module seminars which start one week after the start of the module. These are timetabled locally and details will be announced at the start of each module.

Model solutions to past weeks examples are kept in a file in the Second Year Physics Laboratory.

hide

Term	Code	Module	CATS	List
Term 1	PX266	Geophysics	7.5	List B
	PX267	Hamiltonian Mechanics	7.5	List B
	IL006	Climate Change	7.5/15	Unusual
	PX277	Computational Physics	7.5	List B
Terms 1 & 2	PX262	Quantum mechanics and its Applications	15	List B
Term 2	PX263	Electromagnetic Theory and Optics	7.5	List B
	PX264	Physics of Fluids	7.5	List B
	PX268	Stars	7.5	List B
	PX274	Experimental Particle Physics	7.5	List B
	PX276	Methods of Mathematical Physics	7.5	List B

Philosophy Modules

Students following modules in Philosophy should register for them as normal on the module registration system, but are also encouraged to check with the Philosophy department to ensure that the module still has places available in case it is oversubscribed.

hide

Term	Code	Module	CATS	List
Term 1	PH210	Logic II: Metatheory	15	List B
Terms 1 & 2	PH201	History of Modern Philosophy	30	List B

Warwick Business School

Students intending to transfer at the end of the second year to the joint degree *Mathematics and Business Studies* run by the Warwick Business School should note at the end of the second year students must get at least 50% in any IB coded module, gain an overall honours mark (40% Seymour) and be interviewed by WBS. Information for all WBS modules can be found here.

hide

Term	Code	Module	CATS	List
Term 1	IB133	Foundations of Accounting	12/15	List B
	IB207	Mathematical Programming II	12	List B
Term 2	IB132	Foundations of Finance	12/15	List B
	IB211	Simulation	12	List B
	IB217	Starting a Business	6	List B
	IB3A7	The Practice of Operational Research	12	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.

Plan ahead! 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.

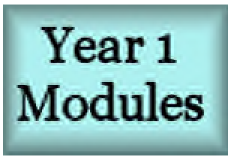
Information on modules can be found at

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

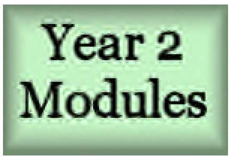
Objectives

After completing the second year the students will have

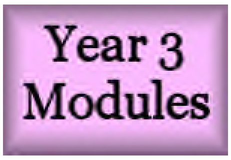
- covered the foundational core;
- had the opportunity to follow options which build on their core knowledge;
- acquired sufficient knowledge and understanding to be in a position to make an informed choice of options in their final years;
- (joint degrees) acquired their core mathematical knowledge and been prepared, through their choice of options, for their final year in the department of their second specialism.



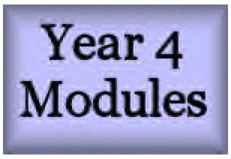
Year 1 regs and modules
G100 G103 GL11 G1NC



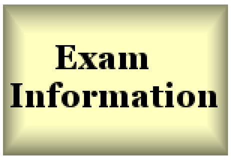
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

New 2nd Year Regulations October 2018

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/changes2018)
Students entering the department from October 2017 onwards will be subject to a revised second year curriculum as outlined below. The core material is essentially the same, but some has been re-organised:

- 2 modules (MA244 Analysis III and MA222 Metric Spaces) will undergo some variation of content (which comes from parts of MA244, MA222 and MA231 Vector Analysis). MA222 will be replaced by MA2yy Norms, Metrics and Topologies (module code to be confirmed). MA2yy syllabus.
- 2 modules (MA231 and MA225 Differentiation) will be removed and replaced by a single new module in term 1, MA2xx Multivariable Calculus (module code to be confirmed). MA2xx syllabus.
- The core will continue to be the same basic content, which will now be in MA244, MA2xx and MA2yy. (Some overlap and some noncore material has been removed in going from 4 modules to 3 modules, and replaced three core modules with three core modules.)

MATHEMATICS BSC. G100

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

Students must take the 6 core modules (total 66 CATS), plus options. List A modules have a high mathematical content. The Core modules are: MA2xx Multivariable Calculus, MA244 Analysis III, MA251 Algebra I, MA249 Algebra II, MA2yy Norms, Metrics and Topologies, MA213 Second Year Essay.

MASTER OF MATHEMATICS MMATH G103

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

The first two years are in common with the BSc Mathematics degree course G100 except that in Year 2 students must take at least 90 CATS credits from the core and List A combined.

To remain on the G103 course at the second year exam board students must have achieved a weighted average on their best 90 CATS of maths modules (Core and List A modules starting with an MA2 code) of a good 2.1 standard. The department strictly interprets this to mean 65.0% or above (if a student has less than 90 CATS of such modules the average os taken over the number of such CATS they have been examined for). Experience has shown that students who do not achieve this threshold struggle with the four year degree, and by being transferred to the BSc. have a better chance of achieving a good 2.1 or first class degree and can plan their future better.

Please note:4th year MMath students are not be able to take second year modules except as unusual options. It is highly unlikely that MA2 modules would be allowed as unusual so choose your modules this year to take this into account.

MATHEMATICS AND BUSINESS STUDIES G1NC

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

Students must take the 6 core modules for G100 students (total 66 CATS), plus one of the List B Warwick Business School modules below (coded IBxxx). To transfer to the Business School at the end of the second year students must get at least 50% in one of these modules, gain an overall honours mark (40% Seymour) and be successfully interviewed by WBS.

MATHEMATICS AND ECONOMICS GL11

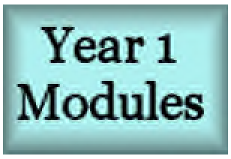
Normal Load = 120 CATS. Maximum Load = 150 CATS.

Year 2 core consists of 60 CATS of Mathematics and 60 CATS of Economics. The Economics modules are EC204 Economics 2 (30 CATS), plus either EC226 Econometrics 1 (30 CATS) or EC220/221 Mathematical Economics 1a and 1b (30 CATS). The Mathematics modules are MA251 Algebra I, MA244 Analysis III, MA2xx Multivariable Calculus, MA2yy Norms, Metrics and Topologies, plus 12 CATS from option list A for the second year of the Mathematics BSc (G100). Students taking EC226 as a core module should consider, as recommended options, ST202 Stochastic Processes and/or ST213 Mathematics of Random Events. Students taking EC220/1 as a core module should consider MA209 Variational Principles.

Note, in year 3 GL11 students transfer to the Economics department where overcatting is not permitted and level 1 modules are also not allowed as options.

MATHEMATICS AND PHILOSOPHY GV17

Second year Mathematics and Philosophy students have transferred to the Philosophy Department and should consult their web pages regarding regulations and options.



Year 1 regs and modules
G100 G103 GL11 G1NC

MA257 Introduction to Number Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma257)
Lecturer: John Cremona

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one hour lectures

Assessment: 2 hour Exam 85%, Homework Assignments 15%

Prerequisites: MA136 Introduction to Abstract Algebra

Co-requisite: MA249 Algebra II: Groups and Rings

Leads To: MA3A6 Algebraic Number Theory, MA426 Elliptic Curves

Content:
• Factorisation, divisibility, Euclidean Algorithm, Chinese Remainder Theorem.
• Congruences. Structure on Z/mZ and its multiplicative group. Theorems of Fermat and Euler. Primitive roots.
• Quadratic reciprocity, Diophantine equations.
• Elementary factorization algorithms.
• Introduction to Cryptography.
• p-adic numbers, Hasse Principle.
• Geometry of numbers, sum of two and four squares.

Aims:
To introduce students to elementary number theory and provide a firm foundation for later number theory and algebra modules.

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

- work with prime factorisations of integers
- solve congruence conditions on integers
- determine whether an integer is a quadratic residue modulo another integer
- apply p-adic and geometry of numbers methods to solve some Diophantine equations
- follow advanced courses on number theory in the third and fourth year

Books:

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.

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

MA257 Forum

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma257/forum)

Search this forum

MA257 Forum

3 followers

1. introductory message

1 post, started by John Cremona, 15:57, Fri 2 Jan 2015

MA209 Variational Principles

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma209)

Lecturer: Vassili Gelfreich

Term(s): Term 3

Status for Mathematics students: List A for Maths

> NOTE: To avoid clashes with April exams this module starts in the 2nd week of Term 3 and is lectured 4 times a week. It overlaps with the 3rd/4th year examination periods in April and May so these students should be aware that they may miss examinable material.

Commitment: 15 lectures

Assessment: One-hour examination

Prerequisites: MA131 Analysis, a module on solving ordinary differential equations (and it is probably a good idea to revise at least separation of variables and linear constant coefficient ODEs) and MA225 Differentiation is also helpful.

Leads To: MA4L3 Large Deviation Theory.

Content: This module consists of a study of the mathematical techniques of variational methods, with applications to problems in physics and geometry. Critical point theory for functionals in finite dimensions is developed and extended to variational problems. The basic problem in the calculus of variations for continuous systems is to minimise an integral of the form

$$I(y) = \int_a^b f(x, y, y_x)\, dx$$

on a suitable set of differentiable functions y: $[a, b] \to \mathbb{R}$ where y_x denotes the derivative of y with respect to x. The Euler-Lagrange theory for this problem is developed and applied to dynamical systems (Hamiltonian mechanics and the least action principle), shortest time (path of light rays and Fermat's principle), shortest length and smallest area problems in geometry. The theory is extended to constrained variational problems using Lagrange multipliers.

Aims: To introduce the calculus of variations and to see how central it is to the formulation and understanding of physical laws and to problems in geometry.

Objectives: At the conclusion of the course you should be able to set up and solve minimisation problems with and without constraints, to derive Euler-Lagrange equations and appreciate how the laws of mechanics and geometrical problems involving least length and least area fit into this framework.

Books:

A useful and comprehensive introduction is:

R Weinstock, *Calculus of Variations with Applications to Physics and Engineering*, Dover, 1974.

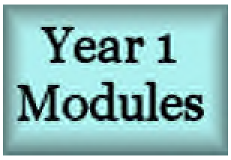
Other useful texts are:

F Hildebrand, *Methods of Applied Mathematics* (2nd ed), Prentice Hall, 1965.

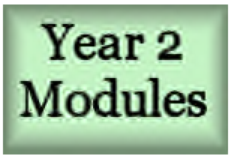
IM Gelfand & SV Fomin. *Calculus of Variations*, Prentice Hall, 1963.

The module will not, however, closely follow the syllabus of any book.

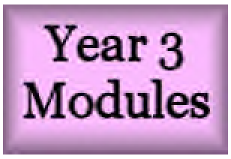
Additional Resources



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

MA213 Second Year Essay

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma213)
Organiser: Daan Krammer

Term(s): Terms 1-2

Status for Mathematics students: Core for all Maths students except GL11 (for whom it is List A).

Commitment: Independent study with guidance from Personal Tutor.

Assessment: Essay 80%, presentation 20%.

Organisation: You can choose your own topic in consultation with your tutor (who must approve it) or base an essay on one of the Maths at Work topics after attending the talks.

Students may, and are strongly advised to, submit a draft of their essay to their tutor by the end of the first week of Term 2. You are expected to have consulted the web pages in the additional resources page on essay writing prior to submission of the draft. The tutor will provide written comments and discuss the draft, normally by Week 4 of Term 2.

Students have to give a 15-minute oral presentation of the essay to their tutor and a small group of other second year students, normally in week 9 of Term 2. This presentation is a compulsory requirement and 20% of the essay mark is allocated to the quality of the presentation. Students should seek advice, e.g. from their tutor, on how to convey the content of their essay within such a short period of time; they must not get bogged down in technicalities but they should not be vague.

Aims:

1. To provide an opportunity for students to learn some mathematics directly from books and other sources.
2. To develop written and oral exposition skills.

Objectives:

1. To learn how to write mathematics well.
2. To practice presenting mathematics orally to a group.
3. To develop research skills, including planning, use of library and the internet.

Deadline The essays should be submitted, in the form of two hard copies and two cover sheets, 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.

It is the students' responsibility to choose their essay topic, to prepare the draft on time, to seek advice where necessary, to prepare the presentation on time and to submit the final version of the essay on time.

The essay will be marked by your tutor and a second marker. Your tutor will also award the mark for the oral presentation. Instructions about the essay and information on the marking scheme will be given out by the end of Term 1. Students are advised to read the instructions carefully, since failure to follow one of the University Regulations (on plagiarism, for example) could result in a mark of zero.

Additional Resources

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

MA222 Metric Spaces

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma222)
Lecturer: Ian Melbourne

Term(s): Term 2

Status for Mathematics students: List A for Maths.

Commitment: Three one hour lectures per week.

Assessment: Two-hour examination 85%, class tests 15%.

Prerequisites: MA132 Foundations (MA138 Sets and Numbers for non-maths students), MA131 Analysis (MA137 Mathematical Analysis for non-maths students) and MA244 Analysis III.

Leads To: The module is a vital prerequisite for most later (especially Pure) Mathematics modules, including MA3F1 Introduction to Topology, MA3D9 Geometry of Curves and Surfaces, MA359 Measure Theory, MA3B8 Complex Analysis, MA371 Qualitative Theory of ODEs, MA3G1 Theory of PDEs, MA3H5 Manifolds, MA424 Dynamical Systems, MA4E0 Lie Groups, MA475 Riemann Surfaces.

Content: Roughly speaking, a metric space is any set provided with a sensible notion of the ``distance'' between points. The ways in which distance is measured and the sets involved may be very diverse. For example, the set could be the sphere, and we could measure distance either along great circles or along straight lines through the globe; or the set could be New York and we could measure distance ``as the crow flies'' or by counting blocks. Or the set might be the set of real valued continuous functions on the unit interval, in which case we could take as a measure of the distance between two functions either the maximum of their difference, or alternatively its ``root mean square''.

This module examines how the important concepts introduced in first year analysis, such as convergence of sequences, continuity of functions, completeness, etc, can be extended to general metric spaces. Applying these ideas we will be able to prove some powerful and important results, used in many parts of mathematics. For example, a continuous real-valued function on a compact metric space must be bounded. And such a function on a connected metric space cannot take both positive and negative values without also taking the value zero. Continuity is readily described in terms of open subsets, which leads us naturally to study the above concepts also in the more general context of a topological space, where, instead of a distance, it is declared which subsets are open.

Aims: To introduce the theory of metric and topological spaces; to show how the theory and concepts grow naturally from problems and examples.

Objectives: To be able to give examples which show that metric spaces are more general than Euclidean spaces, and that topological spaces are yet more general than metric spaces. To be able to work with continuous functions, and to recognize whether spaces are connected, compact or complete.

Books:

W A Sutherland, *Introduction to Metric and Topological Spaces*, OUP.

Other books worth consulting:

E T Copson, *Metric Spaces*, CUP.

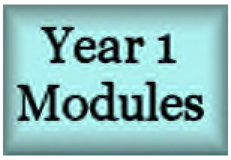
W Rudin, Principles of Mathematical Analysis, McGraw Hill.

G W Simmons, *Introduction to Topology and Modern Analysis*, McGraw Hill. (More advanced, although it starts at the beginning; helpful for several third year and MMath modules in analysis).

A M Gleason, *Fundamentals of Abstract Analysis*, Jones and Bartlett.

D Epstein, Metric Spaces Lecture Notes, 1999-2000, Mathstuff.

Additional Resources



Year 1 regs and modules
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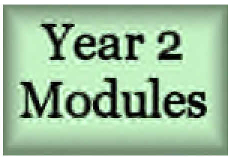

Year 2 regs and modules
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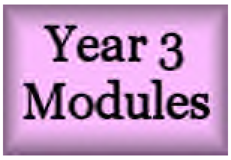

Year 3 regs and modules
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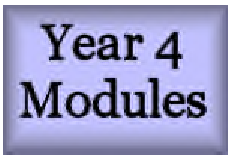
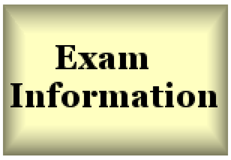


Year 4 regs and modules
G103



Past Exams
Core module averages

MA225 Differentiation

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma225)
Lecturer: Oleg Pikhurko

Term(s): Term 2

Status for Mathematics students: This module is **Core** for all Maths students.

Commitment: Three one-hour lectures per week (Mondays at 17:00, Tuesdays at 14:00, Fridays at 12:00, all in MS.02).

Assessment: Bi-weekly homework assignments (15%), Two-hour examination (85%)

Prerequisites: MA131 Analysis, MA244 Analysis III.

Leads To: MA209 Variational Principles, MA3D9 Geometry of Curves and Surfaces, MA3G7 Functional Analysis I, MA3G8 Functional Analysis II, MA3H5 Manifolds, MA3J3 Bifurcations Catastrophes and Symmetry.

Content: There are many situations in pure and applied mathematics where one has to consider the continuity and differentiability of a function f: $\mathbf{R}^n \to \mathbf{R}^m$, such as the determinant of an $n \times n$ matrix as a function of its entries, or the wind velocity as a function of space and time. It turns out that partial derivatives, while easy to calculate, are not robust enough to yield a satisfactory differentiation theory.

The central object of study in this module is the Fréchet derivative: the derivative of f at a point $x \in \mathbf{R}^n$ is interpreted as a linear transformation $df(x)$: $\mathbf{R}^n \to \mathbf{R}^m$, or $m \times n$ matrix. This module establishes the basic properties of this derivative, which generalise those of single-variable calculus: the usual algebraic rules for differentiation hold true, as do appropriate versions of the chain rule, mean value theorem, Taylor's theorem, and the use of the derivative to find local minima and maxima of a real-valued function. Highlights of the module include the statement and proof of the inverse and implicit function theorems, which have many applications in both geometry and the study of solutions of nonlinear equations, and the Lagrange multiplier theorem for the minimization/maximization of constrained functions.

We will also study norms on infinite-dimensional vector spaces and some applications.

Aims:

1. To develop the theory of the Fréchet derivative as a linear map and study its relationship with the Jacobian matrix of partial derivatives.
2. To extend the results on differentiation of real-valued functions of a single variable to functions between higher-dimensional linear spaces.
3. To introduce the basic theory of normed vector spaces as needed for this theory and to provide a basis for later modules.
4. To show how different branches of mathematics, in this instance linear algebra and analysis, combine to give an aesthetically satisfying and powerful theory.
5. To encourage self-motivated study of mathematics, through examples sheets and further reading.

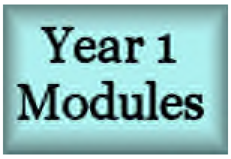
Objectives: By the end of this module students should have a basic working knowledge of higher-dimensional calculus. Students should understand this in the context of normed spaces and appreciate the role this level of abstraction plays in the theory. They should understand basic linear functional analysis to the extent of being able to follow it up in the relevant third year modules. They should also be in a position to make use of more advanced textbooks if they wish to go further into these theories.

Some related books:

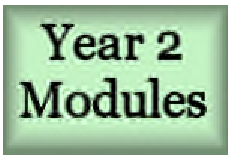
1. R. Abraham, J. E. Marsden, T. Ratiu. *Manifolds, Tensor Analysis, and Applications*. Springer, second edition, 1988.
2. T. M. Apostol. *Mathematical Analysis*. Addison-Wesley Publishing Co., Reading, Mass.-London-Don Mills, Ont., second edition, 1974.
3. R. Coleman. Calculus on normed vector spaces, Springer 2012. [available online via Warwick's library]
4. J. J. Duistermaat, J. A. C. Kolk. Multidimensional Real Analysis I : Differentiation, CUP, 2004 [available online via Warwick's library]
5. T. W. Körner. *A Companion to Analysis: A Second First and First Second Course in Analysis*, volume 62 of Graduate Studies in Mathematics. American Mathematical Society, Providence, RI, 2004.
6. J. E. Marsden and A. Tromba. *Vector Calculus*. Macmillan Higher Education, sixth edition, 2011.
7. J. R. Munkres. *Analysis on Manifolds*. Addison-Wesley Publishing Company, Advanced Book Program, Redwood City, CA, 1991.
8. W. Rudin. *Principles of Mathematical Analysis.* International Series in Pure and Applied Mathematics. McGraw-Hill Book Co., New York-Auckland-Düsseldorf, third edition, 1976.
9. M. Spivak. *Calculus on Manifolds. A Modern Approach to Classical Theorems of Advanced Calculus*. W. A. Benjamin, Inc., New York-Amsterdam, 1965.

Recommended Syllabus

Additional Resources



Year 1 regs and modules
G100 G103 GL11 G1NC



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

MA228 Numerical Analysis

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma228)

Lecturer: Markus Kirkilionis

Term(s): Term 2 (weeks 15-19)

Status for Mathematics students: List A for Maths

Commitment: 15 lectures and 3 computing assignments.

Assessment: By marks from the computing assignments

Prerequisites: MA124 Maths by Computer (MATLAB programming is absolutely essential). MA133 Differential Equations, MA134 3D Geometry and Motion.

Leads To: MA3H0 Numerical Analysis and PDEs.

Content: This module focuses on basic numerical methods for problems arising in mathematics and physics. The important concepts of iteration, convergence, accuracy and stability will be covered. Through implementation of computer algorithms, techniques studied will include Lagrange interpolation, Gaussian quadrature and solving ordinary differential equations by the Runge-Kutta method.

Aims: To introduce the approximation techniques used in tackling mathematical problems which do not yield to exact forms of analysis.

Books: Richard L. Burden and J. Douglas Faires, *Numerical Analysis*, 8th edition, Brooks-Cole Publishing (2004).

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

MA231 Vector Analysis

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma231)
Lecturer: Mario Micallef

Term(s): Term 1

Status for Mathematics students: Core for Maths

Commitment: 30 one-hour lectures

Assessment: 2-hour examination (85%) and coursework (15%)

Prerequisites: MA134 Geometry and Motion or PX129 (Maths/Physics) Worksheets.

Leads To: MA3D1 Fluid Dynamics, MA3G1 Theory of PDEs, MA3D9 Geometry of Curves and Surfaces, MA390 Topics in Mathematical Biology, and various 400 level courses.

Content: The first part of the module provides an introduction to vector calculus which is an essential toolkit for differential geometry and for mathematical modelling. After a brief review of line and surface integrals, div, grad and curl are introduced and followed by the two main results, namely, Gauss' Divergence Theorem and Stokes' Theorem. These theorems will be proved only in simple cases; complete proofs are best deferred until one has learned about manifolds and differential forms. The usefulness of these results in applications to flow problems and to the representation of vector fields with special properties by means of potentials will be emphasized. This leads to Laplace's and Poisson's equations which will be discussed briefly. The solution of these equations are discussed more fully in modules on partial differential equations. Cartesian coordinates are in many cases not well suited to a particular problem: for example, polar coordinates yield simpler equations for the flow of water in a cylindrical pipe. We will show how to represent div, grad and curl in general curvilinear coordinates, paying particular attention to spherical and cylindrical geometries.

The second part of the module introduces the rudiments of complex analysis leading up to the calculus of residues. The link with the first part of the module is achieved by considering a complex valued function of one complex variable as a vector field in the plane. Complex differentiability leads to the Cauchy-Riemann equations which are interpreted as conditions for the vector field to have both zero divergence and zero curl. Cauchy's theorem for complex differentiable functions is then established by means of the main integral theorems of vector calculus. Cauchy's integral formula which expresses the value of a complex differentiable function at a point as a line integral of the function on a contour surrounding the point is the key result from which the stunning properties of complex differentiable functions follow. Many real integrals can be computed using the so-called contour integration in the complex plane. Another interesting features is that complex functions can be expanded in so-called Laurent series around singular points in the plane. A Laurent series is a power series with eventually negative exponents.

Aims: This module aims to

1. Teach a practical ability to work with functions of two or three variables and vector fields;
2. Present the theorems of Gauss and Stokes as generalisations of the fundamental theorem of calculus to higher dimensions;
3. Establish Cauchy's theorem in complex analysis as a consequence of the Cauchy-Riemann equations and the divergence theorems;
4. Teach those rudiments of complex analysis which follow from Cauchy's theorem, namely, the Cauchy integral formula, Taylor expansions, Laurent series and residue calculus.

Objectives: On successful completion of this module, a student should

1. Be able to calculate line, surface and volume integrals in general curvilinear coordinates;

2. Be familiar with and use in a variety of contexts the fundamental results of vector calculus, namely, the divergence theorem and Stokes' theorem;
3. Understand the relation between the existence of a scalar or vector potential of a vector field and the vanishing of the curl or divergence of that vector field and be able to calculate the potential when it exists,
4. Be able to establish the Cauchy-Riemann equations for a complex differentiable function and establish Cauchy's theorem from the integral theorems of vector calculus;
5. Be able to prove Cauchy's integral formula from Cauchy's theorem, and to use the integral formula to establish differentiability and series properties of complex differentiable functions;
6. Be able to calculate Taylor expansions, residues and use them in the evaluation of definite integrals and summation of series.

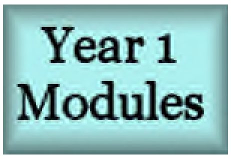
Books:

There are a huge number of books that cover Vector and Complex Analysis at roughly the right level for this course. Comments on a selection of books that are useful for this module will be distributed at the first lecture. In addition lecture notes will be provided; see also

go.warwick.ac.uk/maths/people/staff/stefan_adams/vectoranalysis

Recommended Syllabus

Additional Resources



Year 1 regs and modules
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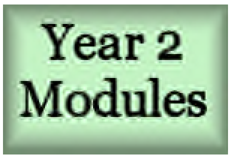

Year 2 regs and modules
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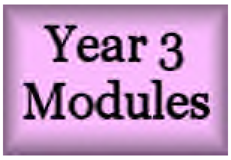
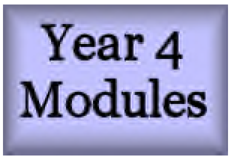
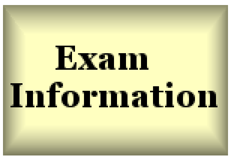


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA241 Combinatorics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma241)
Lecturer: Roman Kotecký

Term(s): Term 1

Status for Mathematics students: List A for Mathematics.

Commitment: 30 lectures.

Assessment: 10% by 4 fortnightly assignments during the term, 90% by a two-hour written examination.

Prerequisites: No formal prerequisites. The module follows naturally from first year core modules and/or computer science option CS128 Discrete Mathematics.

Leads To:

Content:

I Enumerative combinatorics

1. Basic counting (Lists with and without repetitions, Binomial coefficients and the Binomial Theorem)
2. Applications of the Binomial Theorem (Multinomial Theorem, Multiset formula, Principle of inclusion/exclusion)
3. Linear recurrence relations and the Fibonacci numbers
4. Generating functions and the Catalan numbers
5. Permutations, Partitions and the Stirling and Bell numbers

II Graph Theory

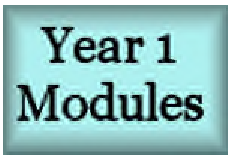
1. Basic concepts (isomorphism, connectivity, Euler circuits)
2. Trees (basic properties of trees, spanning trees, counting trees)
3. Planarity (Euler's formula, Kuratowski's theorem, the Four Colour Problem)
4. Matching Theory (Hall's Theorem and Systems of Distinct Representatives)
5. Elements of Ramsey Theory

III Boolean Functions

Book:
Edward E. Bender and S. Gill Williamson, *Foundations of Combinatorics with Applications*, Dover Publications, 2006. Available online at the author's website: http://www.math.ucsd.edu/~ebender/CombText/

John M. Harris, Jeffry L. Hirst and Michael J. Mossinghoff, *Combinatorics and graph theory*, Springer-Verlag, 2000.

Additional Resources



Year 1 regs and modules
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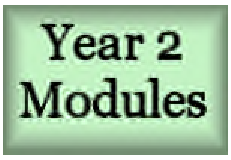

Year 2 regs and modules
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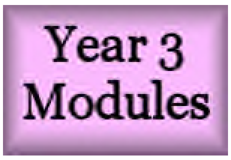

Year 3 regs and modules
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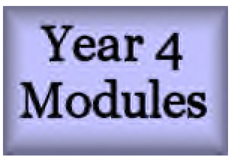

Year 4 regs and modules
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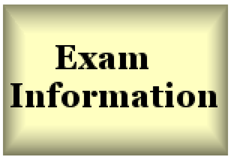


Past Exams

Core module averages

MA243 Geometry

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma243)
Lecturer: Christian Boehning and Liana Heuberger

Term(s): Term 1

Status for Mathematics students: List A for Mathematics

Commitment: 30 lectures plus weekly worksheets

Assessment: The weekly worksheets carry 15% assessed credit; the remaining 85% credit by 2-hour examination.

Prerequisites: None, but an understanding of MA125 Introduction to Geometry will be helpful.

Leads To: Third and fourth year courses in Algebra and Geometry, including: MA3D9 Geometry of Curves and Surfaces, MA3E1 Groups and Representations, MA4A5 Algebraic Geometry, MA4E0 Lie Groups, MA473 Reflection Groups, MA4H4 Geometric Group Theory, MA448 Hyperbolic Geometry and others

Content: Geometry is the attempt to understand and describe the world around us and all that is in it; it is the central activity in many branches of mathematics and physics, and offers a whole range of views on the nature and meaning of the universe.

Klein's Erlangen program describes geometry as the study of properties invariant under a group of transformations. Affine and projective geometries consider properties such as collinearity of points, and the typical group is the full $n \times n$ matrix group. Metric geometries, such as Euclidean geometry and hyperbolic geometry (the non-Euclidean geometry of Gauss, Lobachevsky and Bolyai) include the property of distance between two points, and the typical group is the group of rigid motions (isometries or congruences) of 3-space. The study of the group of motions throws light on the chosen model of the world.

Aims: To introduce students to various interesting geometries via explicit examples; to emphasize the importance of the algebraic concept of group in the geometric framework; to illustrate the historical development of a mathematical subject by the discussion of parallelism.

Objectives: Students at the end of the module should be able to give a full analysis of Euclidean geometry; discuss the geometry of the sphere and the hyperbolic plane; compare the different geometries in terms of their metric properties, trigonometry and parallels; concentrate on the abstract properties of lines and their incidence relation, leading to the idea of affine and projective geometry.

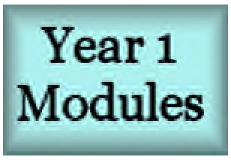
Books:

M Reid and B Szendröi, Geometry and Topology, CUP, 2005 (some Chapters will be available from the General office).

E G Rees, *Notes on Geometry*, Springer

HSM Coxeter, *Introduction to Geometry*, John Wiley & Sons

Additional Resources



Year 1 regs and modules

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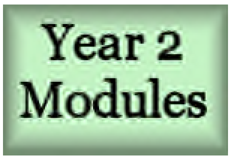

Year 2 regs and modules

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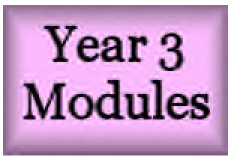


Year 3 regs and modules

G100 G103

MA244 Analysis 3

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma244)

Lecturer: Sergey Nazarenko

Term(s): Term 1

Status for Mathematics students: Core for Maths.

Commitment: 30 lectures

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

This module will be examined in the first week of Term 3.

Prerequisites: MA131 Analysis (MA137 Mathematical Analysis for non-maths students), MA106 Linear Algebra

Leads To: MA222 Metric Spaces, MA225 Differentiation, MA250 Introduction to PDE's, MA359 Measure Theory and MA3G7 Functional Analysis I

Content: This covers three topics: (1) integration, (2) convergence of sequences and series of functions, (3) Norms.

The idea behind integration is to compute the area under a curve. The fundamental theorem of calculus gives the precise relation between integration and differentiation. However, integration involves taking a limit, and the deeper properties of integration require a precise and careful analysis of this limiting process. This module proves that every continuous function can be integrated, and proves the fundamental theorem of calculus. It also discusses how integration can be applied to define some of the basic functions of analysis and to establish their fundamental properties.

Many functions can be written as limits of sequences of simpler functions (or as sums of series): thus a power series is a limit of polynomials, and a Fourier series is the sum of a trigonometric series with coefficients given by certain integrals. The second part of the module develops methods for deciding when a function defined as the limit of a sequence of other functions is continuous, differentiable, integrable, and for differentiating and integrating this limit. Norms are used at several stages and finally applied to show that a Differential Equation has a solution.

Aims:

1. To develop a good working knowledge of the construction of the integral of regulated functions;
2. to study the continuity, differentiability and integral of the limit of a uniformly convergent sequence of functions;
3. to use the concept of norm in a vector space to discuss convergence and continuity there.

Objectives:

1. Understand the need for a rigorous theory of integration, and that this can be developed for regulated functions by approximating the area under the graph by rectangles;
2. understand uniform and pointwise convergence of functions together with properties of the limit function;
3. be able to prove the main results of integration: any continuous function can be integrated on a bounded interval and the Fundamental Theorem of Calculus;
4. prove and apply the Contraction Mapping Theorem.

Books:

No book covers the module although the MathSoc Revision Guide is recommended.

Recommended Syllabus

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/year2/ma244/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 2001/02
Extra Material 1
Extra Material 2
Extra Material 3
Extra Material 4

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

MA250 Introduction to Partial Differential Equations

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma250)
Lecturer: Hugo van den Berg

Term(s): Term 1 (weeks 6-10), Term 2 (weeks 15-19)

Status for Mathematics students: List A

Commitment: 30 lectures

Assessment: 2 hour exam.

Prerequisites: Analytical knowledge as obtained in MA131 Analysis is required. Some techniques on ordinary differential equations as seen in MA133 Differential Equations, on uniform convergence of series as taught in MA244 Analysis III, and on the divergence theorem as presented in MA231 Vector Analysis will be needed and only briefly introduced in the lectures.

Leads To: MA254 Theory of ODEs, MA3G7 Functional Analysis I, MA3D1 Fluid Dynamics, MA3G1 Theory of Partial Differential Equations, MA3G8 Functional Analysis II, MA3H0 Numerical Analysis and PDEs, MA3H7 Control Theory, MA3J4 Mathematical modelling with PDE and MA4L3 Large Deviation theory.

Content:
The theory of partial differential equations (PDE) is important both in pure and applied mathematics. On the one hand they are used to mathematically formulate many phenomena from the natural sciences (electromagnetism, Maxwell's equations) or social sciences (financial markets, Black-Scholes model). On the other hand since the pioneering work on surfaces and manifolds by Gauss and Riemann partial differential equations have been at the centre of many important developments on other areas of mathematics (geometry, Poincare-conjecture).

Subject of the module are four significant partial differential equations (PDEs) which feature as basic components in many applications: The transport equation, the wave equation, the heat equation, and the Laplace equation. We will discuss the qualitative behaviour of solutions and, thus, be able to classify the most important partial differential equations into elliptic, parabolic, and hyperbolic type. Possible initial and boundary conditions and their impact on the solutions will be investigated. Solution techniques comprise the method of characteristics, Green's functions, and Fourier series.

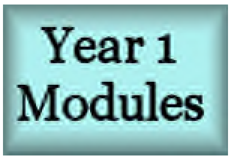
Aims:
To introduce the basic phenomenology of partial differential equations and their solutions. To construct solutions using classical methods.

Objectives:
At the end, you will be familiar with the notion of well-posed PDE problems and have an idea what kind of initial or boundary conditions may be imposed for this purpose. You will have studied some techniques which enable you to solve some simple PDE problems. You will also understand that properties of solutions to PDEs sensitively depend on the its type.

Books:
A script based on the lecturer's notes will be provided. For further reading you may find the following books useful (sections of relevance will be pointed out in the script or in the lectures):

S Salsa: *Partial differential equations in action, from modelling to theory*. Springer (2008).
A Tveito and R Winther: *Introduction to partial differential equations, a computational approach*. Springer TAM 29 (2005).
W Strauss: *Partial differential equations, an introduction*. John Wiley (1992).
JD Logan: *Applied partial differential equations*. 2nd edt. Springer (2004).
MP Coleman: *An introduction to partial differential equations with MATLAB*. Chapman and Hall (2005).
M Renardy and RC Rogers: *An introduction to partial differential equations*, Springer TAM 13 (2004).
LC Evans: *Partial differential equations*. 2nd edt. American Mathematical Society GMS 19 (2010).

Additional Resources



Year 1 regs and modules
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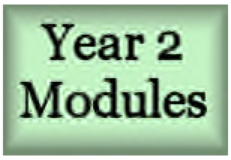

Year 2 regs and modules
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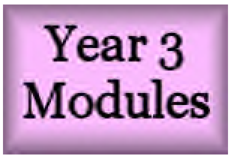

Year 3 regs and modules
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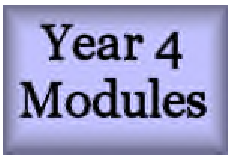
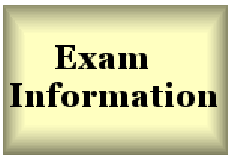


Year 4 regs and modules
G103



Past Exams
Core module averages

MA251 Algebra 1: Advanced Linear Algebra

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma251)
Lecturer: Daan Krammer

Term(s): Term 1

Status for Mathematics students:

Core for Maths.

This module will be examined in Week 30, the first week of Term 3.

Commitment: 30 one-hour lectures plus six assignments

Assessment: Assignments (15%), two-hour examination (85%).

Prerequisites: MA106 Linear Algebra and MA132 Foundations (MA138 Sets and Numbers for non-maths students)

Leads To: third year algebra modules, such as MA3D5 Galois Theory, MA377 Rings and modules. Some of the theory is also needed in MA371 Qualitative Theory of ODEs

Content: This module is a continuation of First Year Linear Algebra. In that course we studied conditions under which a matrix is similar to a diagonal matrix, but we did not develop methods for testing whether two general matrices are similar. Our first aim is to fill this gap for matrices over C. Not all matrices are similar to a diagonal matrix, but they are all similar to one in Jordan canonical form; that is, to a matrix which is almost diagonal, but may have some entries equal to 1 on the superdiagonal.

We next study quadratic forms. A *quadratic form* is a homogeneous quadratic expression $\sum \; a_{ij}x_ix_j$ in several variables. Quadratic forms occur in geometry as the equation of a quadratic cone, or as the leading term of the equation of a plane conic or a quadric hypersurface. By a change of coordinates, we can always write $q(x)$ in the *diagonal form* $\sum \; a_ix_i^2$. . For a quadratic form over , the number of positive or negative diagonal coefficients $a_i$is an invariant of the quadratic form which is very important in applications.

Finally, we study matrices over the integers Z, and investigate what happens when we restrict methods of linear algebra, such as elementary row and column operations, to operations over Z. This leads, perhaps unexpectedly, to a complete classification of finitely generated abelian groups.

Aims: To develop further and to continue the study of linear algebra, which was begun in Year 1.

To point out and briefly discuss applications of the techniques developed to other branches of mathematics, physics, etc.

Objectives: By the end of the module students should be familiar with: the theory and computation of the the Jordan canonical form of matrices and linear maps; bilinear forms, quadratic forms, and choosing canonical bases for these; the theory and computation of the Smith normal form for matrices over the integers, and its application to finitely generated abelian groups.

Books:

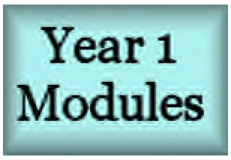
P M Cohn, *Algebra, Vol. 1*, Wiley

I N Herstein, *Topics in Algebra*, Wiley.

Neither is essential, but are a good idea if you are intending to study further algebra modules.

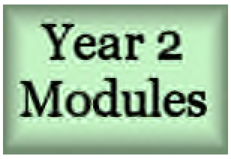
Recommended Syllabus

Additional Resources



Year 1 regs and modules

G100 G103 GL11 G1NC



Year 2 regs and modules

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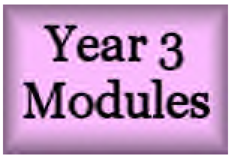
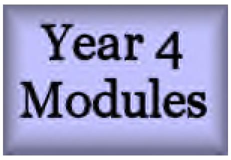


Year 3 regs and modules

G100 G103



Year 4 regs and modules

G103

Exam Information

Past Exams

Core module averages

MA249 Algebra 2: Groups and Rings

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma249)
Lecturer: Dmitriy Rumynin

Term(s): Term 2

Status for Mathematics students: Core for Year 2 mathematics students. It could be suitable as a usual or unusual option for non-maths students

Commitment: 30 lectures.

Assessment: Assignments (15%), two-hour examination (85%)

Prerequisites: MA132 Foundations (MA138 Sets and Numbers for non-maths students), MA106 Linear Algebra, and MA251 Algebra I: Advanced Linear Algebra

Leads To: The results of this module are used in several modules including: MA377 Rings and Modules, MA3A6 Algebraic Number Theory, MA453 Lie Algebras, MA3G6 Commutative Algebra, MA3D5 Galois Theory, MA3E1 Group and Representations, and MA3J3 Bifurcations Catastrophes and Symmetry, although unfortunately not all of these modules are offered every year.

Content: This is an introductory abstract algebra module. As the title suggests, the two main objects of study are groups and rings. You already know that a group is a set with one binary operation. Examples include groups of permutations and groups of non-singular matrices. Rings are sets with two binary operations, addition and multiplication. The most notable example is the set of integers with addition and multiplication, but you will also be familiar already with rings of polynomials. We will develop the theories of groups and rings.

Some of the results proved in MA242 Algebra I: Advanced Linear Algebra for abelian groups are true for groups in general. These include Lagrange's Theorem, which says that the order of a subgroup of a finite group divides the order of the group. We defined quotient groups G/H for abelian groups in Algebra I, but for general groups these can only be defined for certain special types of subgroups *H* of *G*, known as normal subgroups. We can then prove the isomorphism theorems for groups in general. An analogous situation occurs in rings. For certain substructures *I* of rings *R*, known as ideals, we can define the quotient ring R/I, and again we get corresponding isomorphism theorems.

Other results to be discussed include the Orbit-Stabiliser Theorem for groups acting as permutations of finite sets, the Chinese Remainder Theorem, and Gauss' theorem on unique factorisation in polynomial rings.

Aims: To study abstract algebraic structures, their examples and applications.

Objectives: By the end of the module the student should know several fundamental results about groups and rings as well as be able to manipulate with them.

Books:

Complete lecture notes for the module will be available from the General Office soon after the beginning of the spring term, and will appear on the module resources page towards the end of term.

One possible book is

Niels Lauritzen, *Concrete Abstract Algebra*, Cambridge University Press.

Recommended Syllabus

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

MA252 Combinatorial Optimisation

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma252)
Lecturer: Vadim Lozin

Term(s): Term 2

Status for Mathematics students: List A for mathematics

Commitment: 30 lectures.

Assessment: 2 hour exam

Prerequisites: Basic knowledge of discrete mathematics could be helpful.

Leads To:

Content: Many complex everyday problems involve finding an optimal solution in a large, but finite, solution space. Combinatorial optimisation is concerned with the study of effective algorithms for solving such problems by cleverly exploring the solution space. Although many practical problems appear to be insurmountably hard (NP-complete), there are a vast number of problems that can be solved by effective (polynomial time) algorithms.

This module provides an introduction to combinatorial optimisation. In particular, we discuss various fundamental graph-theoretic algorithms. Among others we aim to cover, shortest path algorithms, minimum spanning trees, matching, coverings, network flows, cliques and colorings.

At the end of the course you are expected to have good understanding of various fundamental graph theoretic notions and algorithms. You should also appreciate constructive proofs in finite mathematics.

Books:
W.J. Cook, William H. Cunningham, W. R. Pulleybank, and A. Schrijver, *Combinatorial Optimization,* Wiley-Interscience Series in Discrete Mathematics, 1998.
C.H. Papadimitriou and K. Steiglitz *Combinatorial Optimization: Algorithms and Complexity* *Optimization: Algorithms and Complexity*, Dover Publications, 1998.
Dimitris Bertsimas, John N. Tsitsiklis, *Introduction to linear optimization*, Athena Scientific, c1997
Bernhard Korte and Jens Vygen, *Combinatorial Optimization: Theory and Algorithms,* Springer (any edition)

Additional Resources

Year 1 Modules

Year 1 regs and modules

G100 G103 GL11 G1NC

MA254 Theory of ODEs

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma254)
Lecturer: Claude Baesens

Term(s): Term 2

Status for Mathematics students: List A

Commitment: 30 one hour lectures

Assessment: Two hour exam (100%)

Prerequisites: MA133 Differential Equations (MA113 Differential Equations A for Stats students, although additional reading may be required), MA131 Analysis I-II, MA244 Analysis III, MA106 Linear Algebra and MA251 Algebra 1

Leads to: MA371 Qualitative Theory of ODEs, MA3G1 Theory of PDEs, MA3H0 Numerical Analysis and PDEs, and other modules on modelling, theory and numerics of ODEs and PDEs.

Content:
Many fundamental problems in the applied sciences reduce to understanding solutions of ordinary differential equations (ODEs). Examples include the laws of Newtonian mechanics, predator-prey models in Biology, and non-linear oscillations in electrical circuits, to name only a few. These equations are often too complicated to solve exactly, so one tries to understand *qualitative* features of solutions.

Some questions we will address in this course include:

When do solutions of ODEs exist and when are they unique? What is the long time behaviour of solutions and can they "blow-up" in finite time? These questions culminate in the famous Picard-Lindelof theorem on existence and uniqueness of solutions of ODEs.

The main part of the course will focus on phase space methods. This is a beautiful geometrical approach which often enables one to understand the behaviour of solutions near critical points - often exactly the regions one is interested in. Different trajectories will be classified and we will develop techniques to answer important questions on the stability properties (or lack thereof) of given solutions.

We will eventually apply these powerful methods to particular examples of practical importance, including the Lotka-Volterra model for the competition between two species and to the Van der Pol and Lienard systems of electrical circuits.

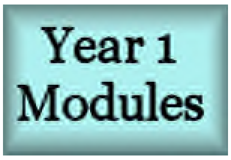
The course will end with a discussion of the Sturm-Liouville theory for solving boundary value problems.

Aims:
To extend the knowledge of first year ODEs with a mixture of applications, modelling and theory to prepare for more advanced modules later on in the course.

Objectives:
1) Determine the fundamental properties of solutions to certain classes of ODEs, such as existence and uniqueness of solutions.
2) Sketch the phase portrait of 2-dimensional systems of ODEs and classify critical points and trajectories.
3) Classify various types of orbits and possible behaviour of general non-linear ODEs.
4) Understand the behaviour of solutions near a critical point and how to apply linearization techniques to a non-linear problem.
5) Apply these methods to certain physical or biological systems.

Books:
(Complete Lecture Notes will be made available)
Ordinary Differential Equations and Dynamical Systems, **Gerald Teschl**, [Available online]
Elementary Differential Equations and Boundary Value Problems, **Boyce DiPrima** 1997
Differential Equations, Dynamical Systems, and an Introduction to Chaos, **Hirsch, Smale** 2003
Nonlinear Systems, **Drazin** 1992

Additional Resources



Year 1 regs and modules
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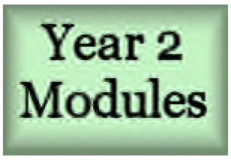

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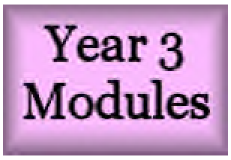

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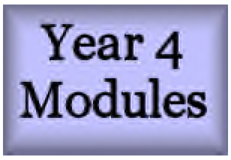

Year 4 regs and modules
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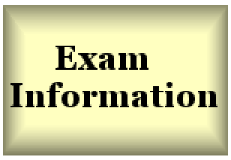


Past Exams
Core module averages

MA256 Introduction to Systems Biology

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma256)
Lecturer: Mike Tildesley

TA:

Term(s): Term 3

Status for Mathematics students: List A

Commitment: 15 one hour lectures

Assessment: One hour exam

Prerequisites: MA133 Differential Equations, MA250 PDE, ST111 Probability A, ST112 Probability B [Recommended: MA254 Theory of ODEs (taken in parallel or previously)]

Course content:

1. General introduction to the course

2. Introduction to Systems Biology

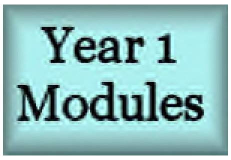
3. Introduction to Epidemiology

Aims:
Introduction to Mathematical Biology and Systems Biology. Modelling techniques (based on core module material).

Objectives:
To develop simple models of biological phenomena from basic principles.
To analyse simple models of biological phenomena using mathematics to deduce biologically significant results.
To reproduce models and fundamental results for a range of biological systems.
To have a basic understanding of the biology of the biological systems introduced.

Books:
H. van den Berg, *Mathematical Models of Biological Systems*, Oxford Biology, 2011
James D. Murray, *Mathematical Biology: I. An Introduction*. Springer 2007
Christopher Fall, Eric Marland, John Wagner, John Tyson, *Computational Cell Biology*, Springer 2002
James Keener, James Sneyd, *Mathematical Physiology I: Cellular Physiology*. Spinger (Interdisciplinary Applied Mathematics) 2008
M J Zvelebil: *Understanding Bioinformatics*, Garland Science, 2007
L. Edelstein Keshet, *Mathematical Models in Biology*, SIAM Classics in Applied Mathematics 46, 2005.

Additional Resources



Year 1 regs and modules
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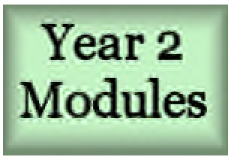

Year 2 regs and modules
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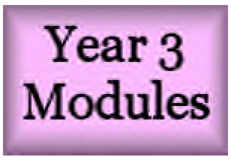

Year 3 regs and modules
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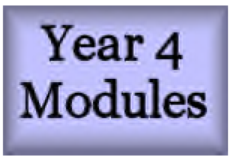
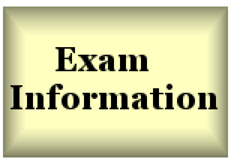


Year 4 regs and modules
G103



Past Exams
Core module averages

ST202: Stochastic Processes

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/st202)
Lecturer(s)

Dr Dario Spanò

Prerequisite(s): Statistics students: ST115 Introduction to Probability and MA137 Mathematical Analysis
Non-Statistics students: ST111/112 Probability A & B and MA131 Analysis I

This module runs in Term 2.

Content: Loosely speaking, a stochastic or random process is something which develops randomly in time. Only the simplest models will be considered in this course, namely those where the process moves by a sequence of jumps in discrete time steps. We will discuss: Markov chains, which use the idea of conditional probability to provide a flexible and widely applicable family of random processes; random walks, which serve as fundamental building blocks for constructing other processes as well as being important in their own right; and renewal theory, which studies processes which occasionally "begin all over again." Such processes are common tools in economics, biology, psychology and operations research, so they are very useful as well as attractive and interesting theories.

Aims: To introduce the idea of a stochastic process, and to show how simple probability and matrix theory can be used to build this notion into a beautiful and useful piece of applied mathematics.

Objectives: At the end of the course students will:

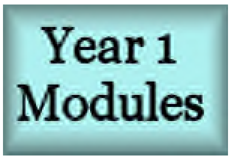
- understand the notion of a Markov chain, and how simple ideas of conditional probability and matrices can be used to give a thorough and effective account of discrete-time Markov chains;
- understand notions of long-time behaviour including transience, recurrence, and equilibrium;
- be able to apply these ideas to answer basic questions in several applied situations including genetics, branching processes and random walks.

***Leads to*:** ST333 Applied Stochastic Processes.

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

Deadline: Assignment 1: week 2, Assignment 2: week 4, Assignment 3: week 6 and Assignment 4: week 8.

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.



Year 1 regs and modules
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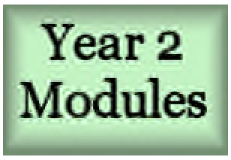
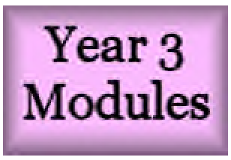


Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
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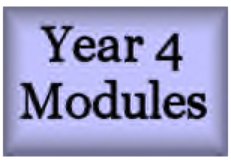

Year 4 regs and modules
G103

Exam Information
Past Exams
Core module averages

ST213 Mathematics of Random Events

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/st213)
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Year 1 Modules
Year 1 regs and modules
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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

ST220: Introduction to Mathematical Statistics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/st220)
Lecturer(s)

Prof Wilfrid Kendall

Prerequisite(s): ST111/2 Probability A&B

Commitment: 3 lectures/week, 5 hours tutorials (and 2 revision lectures in Term 3). This module runs in Term 1.

Aims:
This module is designed for students in the Maths Dept (and other non Statistics dept students). It serves as a prerequisite, replacing ST218/219 Mathematical Statistics A&B, for many of the 3rd year statistics modules.

It will introduce the main ideas of statistical inference emphasising the use of likelihood for estimation and testing. These ideas are fundamental to the use of statistics in modern applications such as mathematical finance, telecommunications, bioinformatics as well as more traditional areas such as insurance, engineering and the social sciences.

Content:

1. Standard families of Probability distributions: Binomial, Geometric, Poisson, Exponential, Gamma, Gaussian.

2. The weak law of large numbers and central limit theorem.

3. The Multivariate Gaussian distribution. Orthogonality and Independence for jointly Gaussian random variables. Distributions derived from the Gaussian: Chi-squared, t and F.

4. The notion of a parametrized Statistical model, and examples.

5. Likelihood including maximum likelihood estimates and use of likelihood ratios to compare hypotheses.

6. The repeated sampling principle: bias and MSE, confidence intervals and p-values.

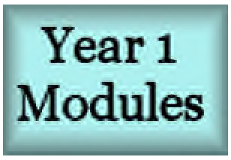
7. Fisher's theorem on Gaussian sampling, and its extension to linear regression.

Books:
Suhov and Kelbert: Probability and Statistics by Example: Basic Probability and Statistics
Casella and Berger: Statistical Inference

Assessment:
100% by examination in June.

Deadlines for handing in assessments:
Assignment 1: week 1, Assignment 2: week 3, Assignment 3: week 5, Assignment 4: week 7 and Assignment 5: week 9.

Feedback: You will hand in answers to selected questions on the fortnightly exercise sheets. Your answers will be marked and returned to you in the tutorial taking place the following week when you will have the opportunity to discuss it.



Year 1 regs and modules
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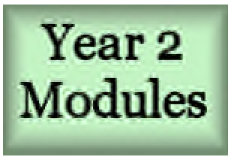
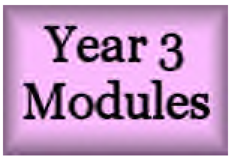
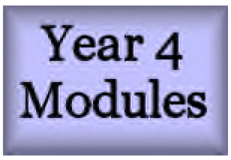


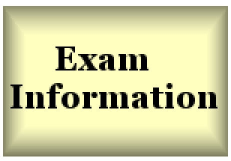
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

ST222: Games, Decisions and Behaviour

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/st222)
Lecturer
Dr Julia Brettschneider

Prerequisite(s): ST115 Introduction to Probability or ST111 Probability A.

Commitment:

3 lectures per week. This module runs in term 1.

Content:

Throughout their history, game and decision theories have used ideas from mathematics and probability to help understand, explain and direct human behaviour.

Questions explored in the module include: What is probability? A set of axioms, a relative amount of outcomes, a belief? And how can this be elicited? What guides decision-making when outcomes are uncertain? What happens when information is only partial or ambiguous? What if there is more than one person, or how are decisions made in games? How do people perceive and evaluate probabilities and risks? Are they acting rationally or not? Which heuristics and biases come into play? Under which conditions do they occur, and how do they impact decision-making?

Answer will be embedded into theories and illustrated with practical examples from a wide range of applications including engineering, economics, finance, business, sciences, psychology and medicine.

Aims:

- Introduce students to several approaches for defining probability with an emphasis on subjective probability
- Develop normative decision theory under uncertainty
- Contrast this with descriptive decision theory and point out models based on behavioural sciences
- Introduce basic game theory

Objectives:

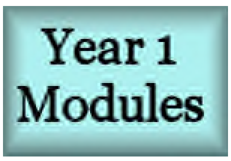
- Students will be familiar with the mathematical and philosophical basis for a number of alternative approaches to probability including subjective probability.
- Students will be familiar with normative decision theory and can apply this to model decision-making in practical examples from a wide range of applications.
- Students will have understood the foundation of and motivation for descriptive decision theory. They will be able to recognise, describe and model deviations from normative theory in examples.
- Students will have basic knowledge of mathematical game theory and can apply this both to mathematical toy example games as well as use game theory to model suitable 'real world' scenarios.

Literature:

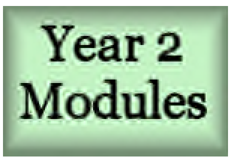
A list with books and website supporting this module will be provided on the resource page for this module. To get a first taste of what the module is about, the following resources may be helpful:

> Koerner, "Naive Decision Making: Mathematics Applied to the Social World" (Cambridge University Press)
> Petersen, "An Introduction to Decision Theory" (Cambridge Introductions to Philosophy)
> Kahneman, "Thinking, fast and slow" (Macmillan)

Assessment:
Exam (100%)



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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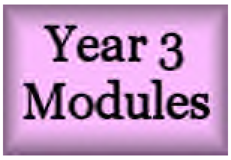
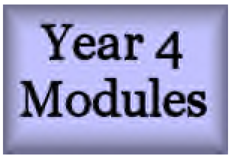
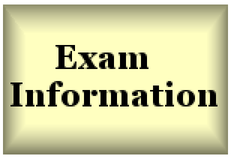


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

EC204 Economics 2

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ec204)

?

CourseSync this module

261 total students

40 total lecture hours

16 total seminars

56 total contact hours

30 CATS - Department of Economics

Principal Aims

The module aims to enable students to develop a deeper understanding of economic concepts introduced in first–year analysis and to introduce new concepts in both micro and macroeconomic analysis. New concepts include material drawn from general equilibrium, welfare economics, game theory, rational expectations and time consistency. The module aims to introduce students to the analysis of public policy issues such as market failure and counter-inflation policy.

Principal Learning Outcomes

By the end of the module, the student will be expected to be familiar with a range of tools for the analysis of both micro and macroeconomic problems. The student will have a rigorous knowledge of the theoretical models which underlie economic analysis and an understanding of both the applicability and the limitations of particular models and approaches.

Syllabus

The module will typically cover the following topics:

Microeconomics The analysis of general equilibrium and welfare economics. Consideration of the economics of public policy issues such as externalities and public goods. Game theoretic approaches to oligopoly, entry and other strategic areas in industrial and business economics.

Macroeconomics The unemployment-inflation relationship. The effect of monetary policy. Expectations, financial markets and the Macroeconomy. Political business cycles. The Time inconsistency problem. The open economy.

Context

Core Module	LM1D (LLD2) - Year 2, V7ML - Year 2, GL11 - Year 2, L1L8 - Year 2, V7MR - Year 2, V7MP - Year 2, R9L1 - Year 2, R3L4 - Year 2, R4L1 - Year 2, R2L4 - Year 2, R1L4 - Year 2
Optional Module	LA99 - Year 2
Pre or Co-requisites	EC106 (for MORSE students) or EC107 or EC131 and EC229 with a mark of 60% in each plus passes in IB121 and IB122
Restrictions	May not be taken by L100 and L116 students or WBS students in their second year. May not be combined with EC201 or EC202.
Part-year Availability for Visiting Students	Available in the Autumn term only (1 x 2000 word essay – 12 CATS) and in the Spring term only (1 x 2000 word essay – 12 CATS) and in the Autumn and Spring terms together (2 x 2000 word essays - 24 CATS)

Assessment

Assessment Method	Coursework (20%) + 3 hour exam (80%)
Coursework Details	Two assignments (2000-word essays) (worth 10% each)
Exam Timing	May/June

Exam Rubric

Time Allowed: 3 hours.

Answer ALL FOUR questions from Section A (40 marks total), ONE question from Section B (30 marks total) and ONE question from Section C (30 marks total). Answer Section A questions in one booklet, Section B questions in a separate booklet; and Section C questions in a separate booklet.

Approved pocket calculators are allowed.

Read carefully the instructions on the answer book provided and make sure that the particulars required are entered on each answer book. If you answer more questions than are required and do not indicate which answers should be ignored, we will mark the requisite number of answers in the order in which they appear in the answer book(s): answers beyond that number will not be considered.

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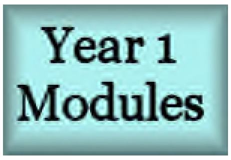
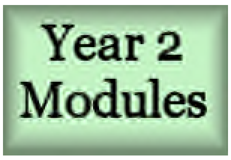
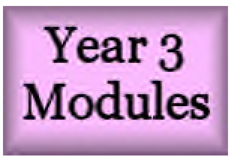
Reading Lists



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

EC220 & 221 Mathematical Economics I

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ec220)

?

CourseSync this module

354 total students

20 total lecture hours

5 total seminars

25 total contact hours

12/15 CATS - Department of Economics

Principal Aims

Mathematical Economics 1a, "Introduction to Game Theory", aims to provide a basic understanding of pure game theory and also introduce the student to a number of applications of game theory to economic problems of resource allocation.

Principal Learning Outcomes

12 CATS - By the end of the module the student should be able to acquire a sense of the importance of strategic considerations in economic problem solving and the normative significance of competitive markets in obtaining Pareto optimal allocations via appropriate extensions of the commodity space. Learn that a few simple, intuitive principles, formulated precisely, can go a long way in understanding the fundamental aspects of many economic problems.
15 CATS - By the end of the module the student should be able to understand the importance of strategic considerations in economic problem solving and the normative significance of competitive markets in obtaining Pareto optimal allocations via appropriate extensions of the commodity space. Learn that a few simple, intuitive principles, formulated precisely, can go a long way in understanding the fundamental aspects of many economic problems.

Syllabus

12 CATS - The module will typically cover the following topics:

Games in strategic form: Nash equilibrium and its applications to voting games, oligopoly, provision of public goods.

Games in extensive form: sub game perfect equilibrium and its applications to voting games, repeated games.

Static games with incomplete information: Bayesian equilibrium and its applications to auctions, contracts and mechanism design.

Dynamic games of incomplete information: Perfect Bayesian equilibrium, Sequential equilibrium and its application to signalling games.

Bargaining theory: Nash bargaining, non-cooperative bargaining with alternating offers and applications to economic markets.

Evolutionary Game Theory

Evolutionary game theory.
15 CATS - The module will typically cover the following topics:

Games in strategic form: Nash equilibrium and its applications to voting games, oligopoly, provision of public goods.

Games in extensive form: sub game perfect equilibrium and its applications to voting games, repeated games.

Static games with incomplete information: Bayesian equilibrium and its applications to auctions, contracts and mechanism design.

Dynamic games of incomplete information: Perfect Bayesian equilibrium, Sequential equilibrium and its application to signalling games.

Bargaining theory: Nash bargaining, non-cooperative bargaining with alternating offers and applications to economic markets.

Evolutionary Game Theory

Context

Core Module	G300 - Year 2, Y602 - Year 2
Optional Core Module	GL11 - Year 2, GL12 - Year 2
Optional Module	LM1D (LLD2) - Year 2, LM1D (LLD2) - Year 3, V7ML - Year 2, V7ML - Year 3, G100 - Year 2, G100 - Year 3, G103 - Year 2, G103 - Year 3, L100 - Year 2, V7MM - Year 4, V7MP - Year 2, V7MP - Year 3, L1P5 - Year 1, L1PA - Year 1, V7MR - Year 2, V7MR - Year 3, LM1H - Year 4, LA99 - Year 2, LA99 - Year 3, L1L8 - Year 2, L1L8 - Year 3, R9L1 - Year 4, R3L4 - Year 4, R4L1 - Year 4, R2L4 - Year 4, R1L4 - Year 4
Pre or Co-requisites	EC120 or EC107 for GL11 students
Pre-requisite for	EC301, EC341
Restrictions	MORSE students must take 12 CAT version.
Part-year Availability for Visiting Students	12 CATS - Not available on a part-year basis 15 CATS - Available in the Autumn term only (1 x test – 12 CATS)

Assessment

Assessment Method	12 CATS - 2 hour exam (100%) 15 CATS - Coursework (20%) + 2 hour exam (80%)
Coursework Details	One 50 minute test (20%)
Exam Timing	May/June

Exam Rubric

Time Allowed: 2 hours.

Answer TWO questions ONLY. All questions carry equal weight (50 marks each). Answer each question in a separate booklet.

Approved pocket calculators are allowed.

Read carefully the instructions on the answer book provided and make sure that the particulars required are entered on each answer book. If you answer more questions than are required and do not indicate which answers should be ignored, we will mark the requisite number of answers in the order in which they appear in the answer book(s): answers beyond that number will not be considered.

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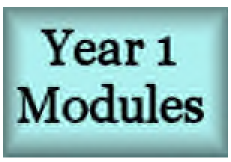
Reading Lists



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

EC220 & 221 Mathematical Economics I

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ec221)

?

CourseSync this module

354 total students

20 total lecture hours

5 total seminars

25 total contact hours

12/15 CATS - Department of Economics

Principal Aims

Mathematical Economics 1a, "Introduction to Game Theory", aims to provide a basic understanding of pure game theory and also introduce the student to a number of applications of game theory to economic problems of resource allocation.

Principal Learning Outcomes

12 CATS - By the end of the module the student should be able to acquire a sense of the importance of strategic considerations in economic problem solving and the normative significance of competitive markets in obtaining Pareto optimal allocations via appropriate extensions of the commodity space. Learn that a few simple, intuitive principles, formulated precisely, can go a long way in understanding the fundamental aspects of many economic problems.
15 CATS - By the end of the module the student should be able to understand the importance of strategic considerations in economic problem solving and the normative significance of competitive markets in obtaining Pareto optimal allocations via appropriate extensions of the commodity space. Learn that a few simple, intuitive principles, formulated precisely, can go a long way in understanding the fundamental aspects of many economic problems.

Syllabus

12 CATS - The module will typically cover the following topics:

Games in strategic form: Nash equilibrium and its applications to voting games, oligopoly, provision of public goods.

Games in extensive form: sub game perfect equilibrium and its applications to voting games, repeated games.

Static games with incomplete information: Bayesian equilibrium and its applications to auctions, contracts and mechanism design.

Dynamic games of incomplete information: Perfect Bayesian equilibrium, Sequential equilibrium and its application to signalling games.

Bargaining theory: Nash bargaining, non-cooperative bargaining with alternating offers and applications to economic markets.

Evolutionary Game Theory

Evolutionary game theory.
15 CATS - The module will typically cover the following topics:

Games in strategic form: Nash equilibrium and its applications to voting games, oligopoly, provision of public goods.

Games in extensive form: sub game perfect equilibrium and its applications to voting games, repeated games.

Static games with incomplete information: Bayesian equilibrium and its applications to auctions, contracts and mechanism design.

Dynamic games of incomplete information: Perfect Bayesian equilibrium, Sequential equilibrium and its application to signalling games.

Bargaining theory: Nash bargaining, non-cooperative bargaining with alternating offers and applications to economic markets.

Evolutionary Game Theory

Context

Core Module	G300 - Year 2, Y602 - Year 2
Optional Core Module	GL11 - Year 2, GL12 - Year 2
Optional Module	LM1D (LLD2) - Year 2, LM1D (LLD2) - Year 3, V7ML - Year 2, V7ML - Year 3, G100 - Year 2, G100 - Year 3, G103 - Year 2, G103 - Year 3, L100 - Year 2, V7MM - Year 4, V7MP - Year 2, V7MP - Year 3, L1P5 - Year 1, L1PA - Year 1, V7MR - Year 2, V7MR - Year 3, LM1H - Year 4, LA99 - Year 2, LA99 - Year 3, L1L8 - Year 2, L1L8 - Year 3, R9L1 - Year 4, R3L4 - Year 4, R4L1 - Year 4, R2L4 - Year 4, R1L4 - Year 4
Pre or Co-requisites	EC120 or EC107 for GL11 students
Pre-requisite for	EC301, EC341
Restrictions	MORSE students must take 12 CAT version.
Part-year Availability for Visiting Students	12 CATS - Not available on a part-year basis 15 CATS - Available in the Autumn term only (1 x test – 12 CATS)

Assessment

Assessment Method	12 CATS - 2 hour exam (100%) 15 CATS - Coursework (20%) + 2 hour exam (80%)
Coursework Details	One 50 minute test (20%)
Exam Timing	May/June

Exam Rubric

Time Allowed: 2 hours.

Answer TWO questions ONLY. All questions carry equal weight (50 marks each). Answer each question in a separate booklet.

Approved pocket calculators are allowed.

Read carefully the instructions on the answer book provided and make sure that the particulars required are entered on each answer book. If you answer more questions than are required and do not indicate which answers should be ignored, we will mark the requisite number of answers in the order in which they appear in the answer book(s): answers beyond that number will not be considered.

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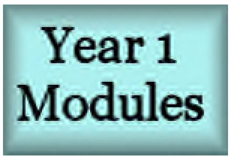
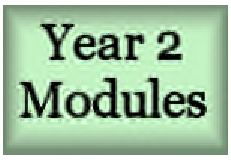
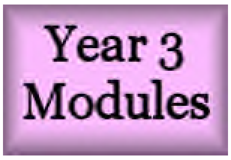
Reading Lists



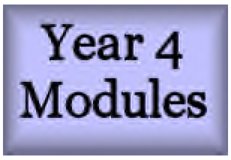
Year 1 regs and modules
G100 G103 GL11 G1NC



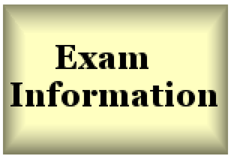
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

EC226 Econometrics 1

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ec226)

?

CourseSync this module

451 total students

50 total lecture hours

18 total seminars

68 total contact hours

30 CATS - Department of Economics

Principal Aims

The course aims to provide students with important skills, which are of both academic and vocational value, being an essential part of the intellectual training of an economist and also useful for a career. In particular the course aims to equip students with the following competencies: 1. An awareness of the empirical approach to economics; 2. Experience in the analysis and use of empirical data in economics; 3. Understanding the nature of uncertainty and methods of dealing with it; 4. The use of econometric software packages as tools of quantitative and statistical analysis.

Principal Learning Outcomes

By the end of the module students will have acquired the necessary skills and knowledge to be able to critically appraise work in the area of applied economics. They will have a good intuitive and theoretical grasp of the dangers, pitfalls and problems encountered in doing applied modelling. The module will also equip students with the necessary background material so that they are able to go on to study more advanced and technical material in the area of econometrics.

Syllabus

The module will typically cover the following topics:

Linear regression model. Least squares estimation. Dummy variables. Linear Restrictions. Classical Linear Regression Model Assumptions. Breakdown of CLRM assumptions. Errors in variables. Heteroscedasticity and implications for OLS. Structural change. Incorrect functional form and implications for OLS. Instrumental variable estimation. Dynamic models with lagged dependent variable. Serial Correlation and implications for OLS. Types of autocorrelation. Nonstationarity and Cointegration. Panel data models. Limited dependent variable models.

Context

Core Module	L100 - Year 2, L116 - Year 2, L1P5 - Year 1, L1PA - Year 1
Optional Core Module	LM1D (LLD2) - Year 2, V7MR - Year 2, GL11 - Year 2, GL12 - Year 2, R9L1 - Year 2, R3L4 - Year 2, R4L1 - Year 2, R2L4 - Year 2, R1L4 - Year 2
Optional Module	V7ML - Year 2, V7ML - Year 3, V7MM - Year 4, V7MP - Year 2, V7MP - Year 3, GL12 - Year 4, GL11 - Year 3
Pre or Co-requisites	EC121 or EC123 and EC124 or EC107 for GL11 students. IB122 for WBS students
Pre-requisite for	EC306, EC338
Restrictions	May not be combined with EC203.
Part-year Availability for Visiting Students	Available in the Autumn term only (1 x test and 1 x assignment – 12 CATS) and in the Autumn and Spring terms together (2 x tests, 2 x assignments and problem sets – 24 CATS)

Assessment

Assessment Method	Coursework (40%) + 3 hour exam (60%)
Coursework Details	Two 50 minute tests (worth 6.67% each) and two assignments (worth 10% each) and problem sets (6.67%)
Exam Timing	May/June

Exam Rubric

Time Allowed: 3 Hours, plus 15 minutes reading time during which notes may be made (on the question paper) BUT NO ANSWERS MAY BE BEGUN.

Answer ALL EIGHT questions from Section A (52 marks total), and THREE questions from Section B (16 marks each). Answer Section A questions in one booklet and Section B questions in a separate booklet.

Approved pocket calculators are allowed. Statistical Tables and a Formula Sheet are provided.

Read carefully the instructions on the answer book provided and make sure that the particulars required are entered on each answer book. If you answer more questions than are required and do not indicate which answers should be ignored, we will mark the requisite number of answers in the order in which they appear in the answer book(s): answers beyond that number will not be considered.

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Reading Lists

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

CS242 Formal Specification and Verification

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs242)
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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

CS243 Data Structures and Algorithms

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs243)
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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

CS244 Algorithm Design

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs244)
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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

CS245 Automata and Formal Languages

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs245)

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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

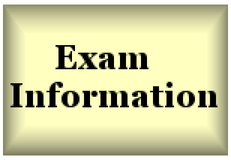
Year 3 regs and modules

G100 G103

Year 4 Modules

Year 4 regs and modules

G103



Past Exams

Core module averages

CS246 Further Automata and Formal Languages

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs246)

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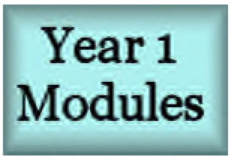
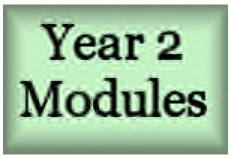


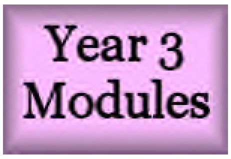
Year 1 regs and modules

G100 G103 GL11 G1NC



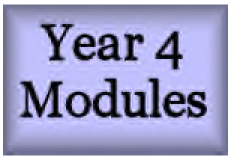
Year 2 regs and modules

G100 G103 GL11 G1NC



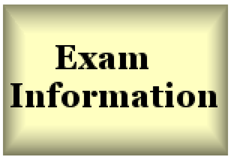
Year 3 regs and modules

G100 G103



Year 4 regs and modules

G103



Past Exams

Core module averages

CS254 Algorithmic Graph Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs254)

Academic Aims

The module is concerned with studying properties of graphs and digraphs from and algorithmic perspective. The focus is on understanding basic properties of graphs that can be used to design efficient algorithms. The problems considered will be typically motivated by algorithmic/computer science/IT applications.

Learning Outcomes

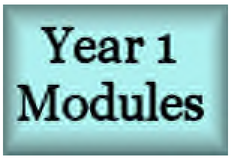
On completion of the module the student shoud be able to:

- understand the basics of graphs, directed graphs, weighted graphs and be able to relate them to practical examples.
- use effectively algorithmic techniques to study basic parameters and properties of graphs.
- design efficient algorithms for various optimisation problems on graphs.
- use effectively techniques from graph theory to approach practical problems in networking and communication.

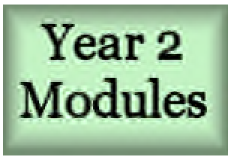
Content

Typical topics include:

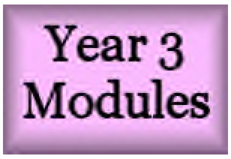
- Introduction to graphs: undirected graphs, directed graphs, weighted graphs, graph representation and special classes of graphs (trees, planar graphs etc.).
- Applications of graphs (in telecommunications, networking etc.).
- Basic algorithmic techniques for graph problems: graph traversals (DFS and BFS), topological sorting, Eular tours.
- Further algorithmic problems on graphs: minimum spanning trees, shortest path problems, matching problems.
- Planar graphs and their properties. Eular's formula, planar separateor theorem and their algorithmic applications.
- Further optimization problems on graphs including graph colouring and graph questions in distributed systems.
- Discussing practical applications of graphs and efficient algorithms for such practical problems. Approximation algorithms and heuristic algorithms. Applications to searching in massive graphs (e.g. page ranking); use of structural properties and algebraic properties.



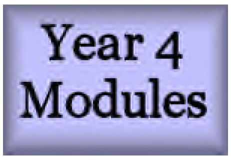
Year 1 regs and modules
G100 G103 GL11 G1NC



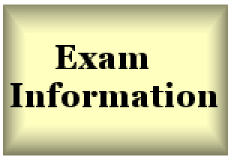
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

CS260 Algorithms

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs260)

Academic Aims

Data structures and algorithms are fundamental to programming and to understand computation. The purpose of this module is to provide students with a coherent introduction to techniques for using data structures and some basic algorithms, and with the tools for applying these techniques to computational problems. Teaching and learning methods include lectures and reading materials which describe algorithmic techniques and applications of these techniques to specific problems. Problem sheets give students opportunities to practice problem solving.

Learning Outcomes

On completion of the module the student will be able to:

- Understand a variety of data structures and be able to use them effectively in design and implementation of algorithms.
- Understand a variety of techniques for designing efficient algorithms, proving their correctness, and analyzing their efficiency.

- Understand some fundamental algorithmic problems and algorithms for solving them.

Content

- Basics of algorithm analysis.
- Elementary graph algorithms.
- Greedy algorithms.
- Divide-and-conquer algorithms.
- Dynamic programming.
- Network flows.
- NP and computational intractability.

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

Year 2 Modules

Year 2 regs and modules
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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

CS262 Logic and Verification

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/cs262)

Academic Aims

To give students an understanding of the basics of mathematical logic, and its applications to specifying and verifying computing systems. Algorithms and proof calculi for verification, as well as associated tools, will be studied. Theory and practice relating to reliability of systems form a vital part of computer science.

Learning Outcomes

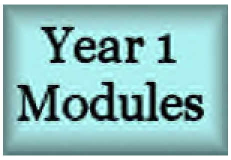
On completion of the module the student will be able to:

- Construct and reason about proofs in a variety of logics.
- Understand and compare the semantics of a variety of logics.
- Apply logic to specify and verify computing systems.
- Understand basic algorithms for formal verification.

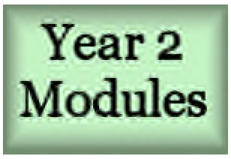
- Use formal verification tools.

Content

- Propositional logic: proofs, semantics, normal forms, SAT solvers.
- Predicate logic: proofs, semantics.
- Specifying and modelling software.
- Verification by model checking.
- Proof calculi for program verification.



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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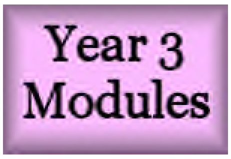

Year 3 regs and modules
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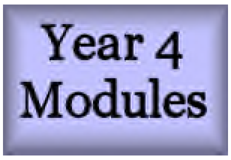
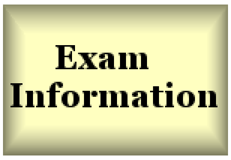


Year 4 regs and modules
G103



Past Exams
Core module averages

PX261 Mathematical Methods for Physicists II

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px261)
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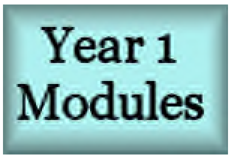

Year 1 regs and modules
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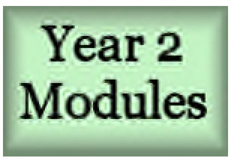

Year 2 regs and modules
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PX262 Quantum Mechanics and its Applications

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px262)

Lecturers: Gavin Bell and Nicholas d'Ambrumenil

Weighting: 15 CATS

The first part of this year's module uses ideas, introduced in the first year module, to explore atomic structure. The module also covers the mathematical tools needed in quantum mechanics and outlines the fundamental postulates that form the basis of the theory. The module discusses the time-independent and the time-dependent Schrödinger equations for spherically symmetric and harmonic potentials, angular momentum and hydrogenic atoms.

The second half of the module looks at many-particle systems and aspects of the standard model of particle physics. The module introduces the quantum mechanics of free fermions and discusses how it accounts for the conductivity and heat capacity of metals and the state of electrons in white dwarf stars. Introducing the effect of the ionic lattice and the scattering of electrons off ions then leads to a description of the properties of semiconductors and insulators. The standard model of particle physics is a quantum field theory and beyond simple quantum mechanics. However, using ideas from quantum mechanics, it is possible to explain a number of aspects of the standard model such as antiparticles and particle oscillations.

Aims:

To introduce the mathematical structure of quantum mechanics and to explain how to compute expectation values for observable quantities of a system. To show how quantum theory accounts for properties of atoms, elementary particles, nuclei and solids.

Objectives:

To develop the foundations of quantum mechanics. At the end of the module you should:

- know the origin of the *n*,*l*,*m* and *s* quantum numbers and be able to use the Pauli exclusion principle to explain the periodic table.
- understand the significance of Hermitian operators and eigenvalue equations and be able to use the correspondence principle to find the form of a quantum mechanical operator.
- be able to use quantum mechanics to derive a description of the electron states of the hydrogen atom.
- be familiar with the free-electron model of a metal
- be aware of the different crystal lattice types and how waves in a crystal are scattered by the ions
- be able to describe the elements of the standard model and to apply simple ideas from quantum theory to explain phenomena observed in particles and nuclei

Syllabus:

Revision of wavefunctions, probability densities and the Schrödinger equation in 1 dimension. The hydrogen atom: orbital angular momentum, quantum numbers, probability distributions. Atomic spectra and Zeeman effect. Electron spin: Stern-Gerlach, spin quantum numbers, spin-orbit coupling, exclusion principle and periodic table. X-ray spectra.

Formal Quantum Mechanics
The first postulate - the wavefunction to describe the state of a system; the principle of superposition of states; Operators and their rôle in quantum mechanics; the correspondence principle; measurement, Hermitian operators and eigenvalue equations; the uncertainty principle - compatibility of measurements and commuting of operators; the time dependent Schrödinger equation.

The quantum harmonic oscillator, creation and annihilation operators.

Angular momentum
The angular momentum operators and their commutators; the eigenvalues of the angular momentum operators, the l and m quantum numbers; the eigenfunctions of the angular momentum operators, the Spherical Harmonics. The hydrogen atom revisited.

Models of Matter
Statement of the many body problem. Why do molecules, nuclei and solids form? The **free fermion model** model, the Fermi surface, density of states. Fermi-Dirac distribution. Heat capacity, magnetic susceptibility, Pauli paramagnetism, ferromagnetism. Current in quantum mechanics and conductivity in a metal. Fermion degeneracy in white dwarf and neutron stars, gravitational collapse. The **liquid drop model** of the nucleus, energy release in fission. The **crystal lattice**: Lattices as repeated cells, unit cell. Lattice types in 3D: Simple cubic, BCC, FCC, other types. Reciprocal lattice vectors, relation to material on Fourier series. Planes and indices. X-ray diffraction. The **nearly free electron model**, scattering of electron waves by a periodic lattice and band structure. Insulators and semiconductors. Semiconductor devices, e.g. diode, LED.

The Standard Model
The constituents of the standard model and the use of natural units. Klein-Gordon and Dirac equations. Examples of quantum mechanics 'in action' in the standard model: antiparticles and the origin of spin, W± exchange and Fermi's contact interaction.

Constructing Models
Relation between quantum mechanics and linear algebra. Dirac's bra-ket notation. Modelling the ammonia clock. Neutrino oscillations, kaon decay.

Commitment: about 40 Lectures + problems classes

Assessment: 2 hour examination (85%) + assessed work (15%).

Recommended Text: H D Young and R A Freedman, University Physics, Pearson, AIM Rae, *Quantum Mechanics*, IOP

Other useful books: P.C.W. Davies and D.S. Betts, *Quantum Mechanics*, Chapman and Hall 1994; F. Mandl, *Quantum Mechanics*, John Wiley 1992, S McMurry, *Quantum Mechanics*, Addison-Wesley.

This module has a home page.

Leads from: PX101 Quantum Phenomena

Leads to: PX382 Quantum Physics of Atoms, PX395 The Standard Model, PX385 Condensed Matter Physics

Year 1 Modules

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Year 2 Modules

Year 2 regs and modules
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Year 3 Modules

Year 3 regs and modules
G100 G103

Year 4 Modules

Year 4 regs and modules
G103