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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 study a refreshed second year curriculum where the essential core material has been included in fewer core modules with less overlap.

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: MA259 Multivariable Calculus, MA244 Analysis III, MA251 Algebra I, MA249 Algebra II, MA260 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 is 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. For students who take 90 CATS of List A, but less than 90 CATS of MA2 modules, we would take the average over the MA2 modules that have been taken, and then look at the overall mark profile, invcluding the other List A modules taken, to make a progression decision on a case by case basis.

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 WITH 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% end of year) 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, MA259 Multivariable Calculus, MA260 Norms, Metrics and Topologies, plus 12 CATS from option list A/Core 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 MA259 Multivariable Calculus, 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	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
	MA259	Multivariable Calculus	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
	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
	MA260	Norms, Metrics and Topologies	12	Core	Core
Term 3	MA209	Variational Principles	6	List A	List A
	MA256	Introduction to Systems Biology	6	List A	List A

Interdisciplinary Modules (IATL and GSD)

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 (this module is run by Global Sustainable Development from 2018 on).

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 the year. 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, the Economics department 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. Please contact the Physics department to answer any queries concerning their second year 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.

PLEASE NOTE: from 2019/20 3rd years will NOT be allowed to take IB132 or IB133 as unusual options (or any other IB1xx module), so if you wish to take one/both of these during your degree you must do so this year.

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

Film and Television Studies

Back on List B after being absent for a number of years. In the past this has been a popular choice for Maths students looking for something a bit different.

hide

Term	Code	Module	CATS	List
Term 1 and 2	FI101	Discovering Cinema	12/24 (TBC)	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 (as an Unusual Option) 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. We used to restrict maths students to 24 (12) if there was a choice, but we no longer do this.

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 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

FI101 Discovering Cinema

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/fi101)
Note: full module page can be found at this link, the below is so that the entry appears on the PDF version of the handbook!

Module Tutors:
Dr Matt Denny

Leanne Weston

***** Important Note for Week One *****
Please note there will be no seminars in Week 1 of the Autumn term. There will be time set aside in the lecture for you to record your availability so that you can be assigned to a seminar group

This module is intended to introduce students to the techniques and skills of textual analysis and to develop their understanding and appreciation of cinema both past and present. It aims to introduce cinema through a range of critical lenses and frameworks, familiarising students with key formal strategies and critical concepts that are necessary for analysing films. It is designed to ensure that students are adept at examining the various visual, aural and narrative conventions by which they create meaning and how these meanings have been understood within the academic field of film studies.

The module is divided into two parts. During the first term the module offers students various methods for developing and applying the critical vocabulary required to analyse formal elements of cinema such as *mise-en-scène*, editing, staging, and composition Before moving to explore filmmaking across a number of historical, national, and stylistic modes in the final weeks. In the second term the module moves on to cover key theoretical concerns in film studies, such as authorship, genre, and stardom. The impact of the industry on filmmaking will also be considered.

Students will explore these ideas through a wide and engaging array of films from different countries and different periods in the history of cinema. By focusing on a range of narrative films, this module will ultimately equip students with the necessary analytical skills to discover cinema's richness, its complexity and its expressiveness.

This course will be taught through a combination of lectures, seminars and weekly screenings. Attendance at lectures, seminars and screenings is compulsory.

Aims and Objectives

- This module aims to introduce and familiarise students with the principles of film form, narrative and style as well as the basic methodologies of film criticism.
- This module will introduce students to some of the key theoretical concepts in film studies, including debates on genre, stardom, and authorship and the impact of the industry on filmmaking
- It intends to equip students with a critical vocabulary for analysing films and will give them significant practice in discussing and writing about cinema.
- It will allow students to develop a scholarly understanding of some of the dominant concepts, methods and debates in film studies.
- It gives students the opportunity to study historical and contemporary cinemas from Europe, Asia and the Americas and enables them to explore a variety of critical and theoretical approaches to studying this exciting medium.

Intended Outcomes

By completing the module, including all its assessment components, students will be able to:

- Analyse the formal properties of a narrative film, including its *mise-en-scène*, cinematography, editing, sound and style.
- Apply the principles of textual analysis to a variety of film texts.
- Understand the basics of some of the main approaches in film studies such as *mise-en-scène* criticism .
- Demonstrate competence in writing critically about film.
- Demonstrate fundamental skills in the close formal, thematic, industrial, and theoretical analysis of different kinds of cinema

Timetable:

Tuesday

1200 – 1300 Lecture A0.28 Millburn House
1300 – 1500 Film Screening 2 A0.28 Millburn House*

Wednesday
Seminars (Attend ONE) A1.24/A1.28 Millburn House
1200 – 1300 or 1300 – 1400 or 1400 – 1500

*If you cannot make the Tuesday screening you MUST attend the Monday screening at 0900 – 1200 in A1.25 Millburn House

Reccommend Reading
The following books will be useful for reference throughout the course. It would be a good idea to be acquainted with them early on:
• David Bordwell and Kristin Thompson, Film Art: An Introduction (New York: McGraw Hill, 2013)
• Film Moments: Criticism, History, Theory, eds. Tom Brown and James Walters (London: BFI, 2010)
• Pam Cook, The Cinema Book (London: BFI, 2007)
• John Gibbs, Mise-en-scène: Film Style and Interpretation (London: Wallflower, 2002)
• Adrian Martin, Mise en scene and film style: from classical Hollywood to new media art, (Basingstoke: Palgrave Macmillan, 2014) [NB: This is a more advanced text, but does feature an excellent introduction covering the history of mise-en-scene analysis]
• V.F. Perkins, Film as Film: Understanding and Judging Movies (New York: Da Capo Press, 1993)

MA259 Multivariable Calculus

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma259)
Lecturer: Dr. Mario Micallef

Term(s): 1

Status for Mathematics students: Core

Commitment: 30 lectures

Assessment: 85% by examination, 15% by assignments

Prerequisites: MA131 Analysis I and II OR MA137 Mathematical Analysis, MA106 Linear Algebra, MA134 Geometry and Motion OR PX129 Tutorial

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:

• Continuous Vector-Valued Functions
• Some Linear Algebra
• Differentiable Functions
• Inverse Function Theorem and Implicit Function Theorem
• Vector Fields, Green's Theorem in the Plane and the Divergence Theorem in $\mathbb{R}^3$
• Maxima, minima and saddles

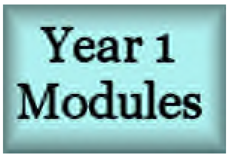
Learning Outcomes:

- Demonstrate understanding of the basic concepts, theorems and calculations of multivariate analysis.
- Demonstrate understanding of the Implicit and Inverse Function Theorems and their applications.
- Demonstrate understanding of vector fields and Green's Theorem and the Divergence Theorem.
- Demonstrate the ability to analyse and classify critical points using Taylor expansions.

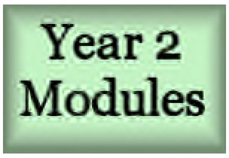
Books:

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.

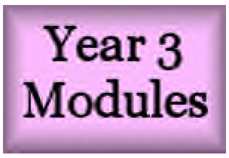
Additional Resources



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

MA260 Norms Metrics and Topologies

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma260)
Lecturer: Professor James Robinson

Term(s): 2

Status for Mathematics students: Core

Commitment: 30 lectures

Assessment: 85% by examination, 15% by assignments

Prerequisites: MA131 Analysis I and II OR MA137 Mathematical Analysis, MA224 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:

To introduce the notions of Normed Space, Metric Space and Topological Space, and the fundamental properties of Compactness, Connectedness and Completeness that they may possess. Students will gain knowledge of definitions, theorems and calculations in

- Normed, Metric and Topological spaces
- Open and closed sets and their relation to continuity
- Notions of Compactness and relations to continuous maps
- Notions of Connectedness and relations to continuous maps
- Notions of Completeness and relations to previous topics in the module.

The module comprises the following chapters:

- Normed Spaces
- Metric Spaces
- Open and closed sets
- Continuity
- Topological spaces
- Compactness
- Connectedness
- Completeness

Learning Outcomes:

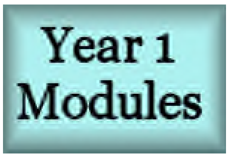
- Demonstrate understanding of the basic concepts, theorems and calculations of Normed, Metric and Topological Spaces.
- Demonstrate understanding of the open-set definition of continuity and its relation to previous notions of continuity, and applications to open or closed sets.
- Demonstrate understanding of the basic concepts, theorems and calculations of the concepts of Compactness, Connectedness and Completeness (CCC).
- Demonstrate understanding of the connections that arise between CCC, their relations under continuous maps, and simple applications.

Books:

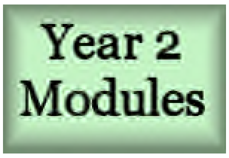
1. W A Sutherland, *Introduction to Metric and Topological Spaces*, OUP.
2. E T Copson, *Metric Spaces*, CUP.
3. W Rudin, *Principles of Mathematical Analysis*, McGraw Hill.

4. 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).
5. A M Gleason, *Fundamentals of Abstract Analysis*, Jones and Bartlett.

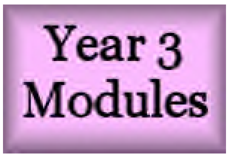
Additional Resources



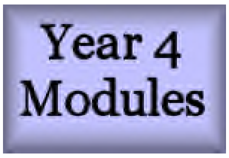
Year 1 regs and modules
G100 G103 GL11 G1NC



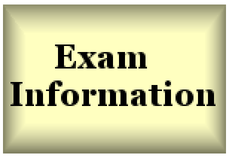
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA257 Introduction to Number Theory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma257)
Lecturer: Dr. Adam Harper

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.

MA257 Forum

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

Search this forum

MA257 Forum
2 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 MA259 Multivariable Calculus 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.

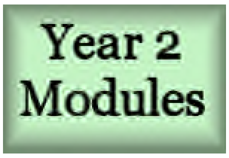
The module will not, however, closely follow the syllabus of any book.

Additional Resources

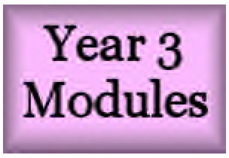
Archived Pages: Pre-2011 2011 2012 2013 2014 2015 2016 2017

Year 1 Modules

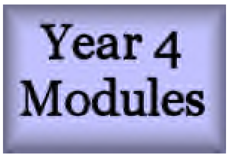
Year 1 regs and modules
G100 G103 GL11 G1NC



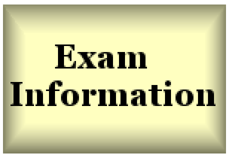
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

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.

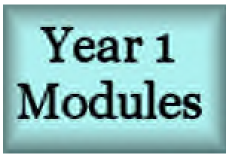
Deadline The essays should be submitted, in the form of two hard copies and two cover sheets, to the Undergraduate Office by 12:00 noon on Thursday of the first week of Term 3. *This deadline is enforced* by the mechanism described in the Course Handbook section on Assessment.

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.

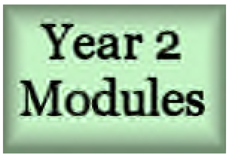
The essay will be marked by your tutor and a second marker. Your tutor will also award the mark for the oral presentation. Instructions about the essay and information on the marking scheme will be given out by the end of Term 1. Students are advised to read the instructions carefully, since failure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

Additional Resources

Archived Pages: 2012 2014 2015 2017



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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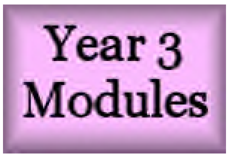
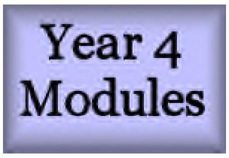
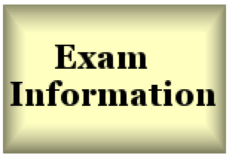


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA222 Metric Spaces

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

Term(s): Term 2

Status for Mathematics students: List A for Maths.

Commitment: Three one hour lectures per week.

Assessment: Two-hour examination 85%, assignments 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.

The detailed **course program**, which can also serve as a list of things that would be good to know before the exam (or a class test), can be found here .

The following **books**, jointly covering the course material, are available for download via the University Library:

- Topology: an Introduction. S. Waldmann. Springer, 2014.
- First Course in Metric Spaces. B. K. Tyagi. Foundation Books, 2012.
- Elementary Theory of Metric Spaces: a Course in Constructing Mathematical Proofs. R. B. Reisel. Springer New York, 1982.
- Metric Spaces. E.T. Copson. Cambridge University Press, 1968.

In addition, I can also recommend an excellent synopsis by David Preiss (from 2015) and complete lecture notes by David Epstein (from 2000).

Furthermore, the library has a few hard copies of the old book by W. A. Sutherland, *Introduction to Metric and Topological Spaces*, which one can also refer to.

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

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 $f\colon \mathbf{R}^n \to \mathbf{R}^m$, 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 $df(x)\colon \mathbf{R}^n \to \mathbf{R}^m$, 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 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

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

Archived Pages: Pre-2011 2011 2012 2013 2014 2015 2016 2017

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

Archived Pages: Pre-2011 2011 2012 2013 2014 2015 2016 2017

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

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

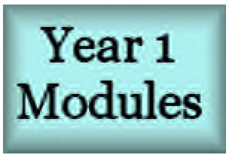
III Boolean Functions

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/

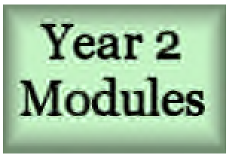
John M. Harris, Jeffry L. Hirst and Michael J. Mossinghoff, *Combinatorics and graph theory*, Springer-Verlag, 2000.

Additional Resources

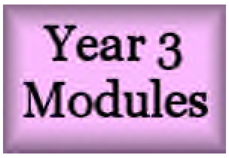
Archived Pages: 2011 2012 2014 2015 2016 2017



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 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

MA243 Geometry

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

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

Archived Pages: 2013 2014 2015 2016 2017

Year 1 Modules

Year 1 regs and modules
G100 G103 GL11 G1NC

MA244 Analysis 3

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

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: MA260 Norms, Metrics and Topologies, MA250 Introduction to PDE's, MA359 Measure Theory and MA3G7 Functional Analysis I

Content: This covers three topics: (1) Riemann integration, (2) convergence of sequences and series of functions, (3) introduction to complex valued functions.

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.

The final part of module focuses on complex valued functions, starting with the notion of complex differentiability. The module extends the results from Analysis II on power series to the complex case. The final section focuses on contour integrals, where a complex valued function is integrated along a curve. Cauchy's integral formula will be developped and a series of applications presented (to compute integrals of real valued functions, Liouville's Theorem and the Fundamental Theorem of Algebra).

Learning outcomes:

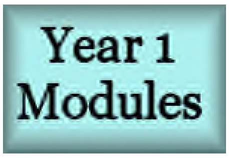
1. To develop a good working knowledge of the construction of the Riemann integral;
2. to understand the fundamental properties of the integral; main ones include: any continuous function can be integrated on a bounded interval and the Fundamental Theorem of Calculus (and its applications);

3. to understand uniform and pointwise convergence of functions together with properties of the limit function;
4. to study the continuity, differentiability and integral of the limit of a uniformly convergent sequence of functions;
5. to study complex differentiability (Cauchy-Riemann equations) and complex power series;
6. to study contou integrals: Cauchy's integral formulas and applications.

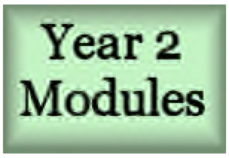
Books:

Additional Resources

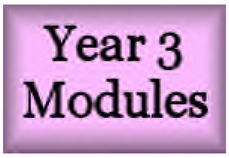
Archived Pages: Pre-2011 2011 2012 2013 2015 2016 2017



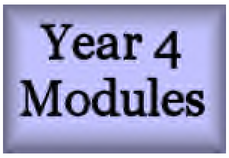
Year 1 regs and modules
G100 G103 GL11 G1NC



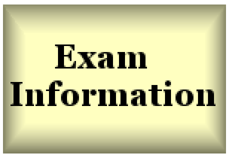
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

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

MA250 Introduction to Partial Differential Equations

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma250)
Lecturer: Dr. Björn Stinner

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 MA259 Multivariable Calculus 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.

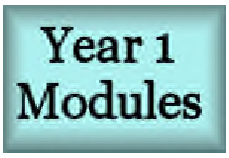
Objectives:
At the end, you will be familiar with the notion of well-posed PDE problems and have an idea what kind of initial or boundary conditions may be imposed for this purpose. You will have studied some techniques which enable you to solve some simple PDE problems. You will also understand that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

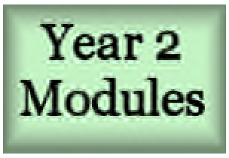
S Salsa: *Partial differential equations in action, from modelling to theory*. Springer (2008).
A Tveito and R Winther: *Introduction to partial differential equations, a computational approach*. Springer TAM 29 (2005).
W Strauss: *Partial differential equations, an introduction*. John Wiley (1992).
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

Archived Pages: 2013



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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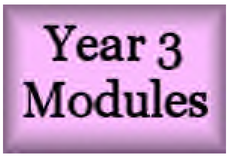
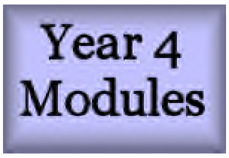
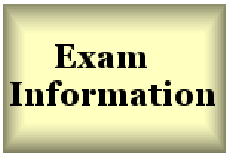


Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

MA251 Algebra 1: Advanced Linear Algebra

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma251)
Lecturer: Professor Derek Holt

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 $\sum a_{ii}x_ix_j$ 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 R, 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

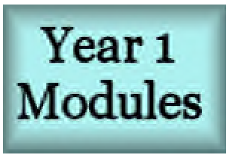
I N Herstein, *Topics in Algebra*, Wiley.

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

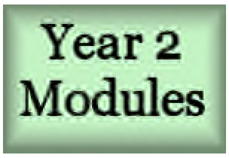
Recommended Syllabus

Additional Resources

Archived Pages: 2011 2012 2014 2015 2016 2017



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
G100 G103 GL11 G1NC

MA249 Algebra 2: Groups and Rings

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ma249)
Lecturer: Dr. Inna Capdeboscq

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:

One possible book is

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

Recommended Syllabus

Additional Resources

Archived Pages: 2012 2013 2014 2015 2016 2017

MA252 Combinatorial Optimisation

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

Term(s): Term 2

Status for Mathematics students: List A for mathematics

Commitment: 30 lectures.

Assessment: 2 hour exam

Prerequisites: No formal prerequisites. Students who have taken CS126, CS137, MA241 or CS260 will find it helpful, but no background from these modules will be assumed.

Leads To: This module may be useful for students interested in taking MA241, MA3J2 or MA4J3, but it is not a formal prerequisite for them.

Content: The focus of combinatorial optimisation is on finding the "optimal" object (i.e. an object that maximises or minimises a particular function) from a finite set of mathematical objects. Problems of this type arise frequently in real world settings and throughout pure and applied mathematics, operations research and theoretical computer science. Typically, it is impractical to apply an exhaustive search as the number of possible solutions grows rapidly with the "size" of the input to the problem. The aim of combinatorial optimisation is to find more clever methods (i.e. algorithms) for exploring the solution space.

This module provides an introduction to combinatorial optimisation. Our main focus is on several fundamental problems arising in graph theory and linear programming and algorithms developed to solve them. These include problems related to shortest paths, minimum weight spanning trees, linear programming, matchings, network flows, cliques, colourings, dynamic programming, multicommodity flows and matroids. We will also discuss "intractible" (e.g. NP-hard) problems.

Preliminary Schedule:

A preliminary schedule for the 2018-2019 edition of the module can be found here.

Main Reference:

- A. Schrijver, *A Course in Combinatorial Optimization*, Unpublished Lecture Notes, 2017. Available through the link.[1]

Other Resources:

- D. Bertsimas, J. N. Tsitsiklis, *Introduction to linear optimization*, Athena Scientific, c1997
- A. Bondy and U. S. R. Murty, *Graph Theory with Applications*, Elsevier, 1976. Available through the link.
- M. Goemans, *Combinatorial Optimisation*, Unpublished Lecture Notes. Available through the link (scroll down after clicking the link).[1]
- B. Korte and J. Vygen, *Combinatorial Optimization: Theory and Algorithms*, Springer, 6th Edition, 2018. E-book available through the Warwick Library; click the link.
- A. Schrijver, *Advanced Graph Theory and Combinatorial Optimization*, Unpublished Lecture Notes. Available for free through the link.[1]
- 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.
- D. P. Williamson, *Mathematical Programming I*, Unpublished Lecture Notes. Available through the link (scroll down after clicking the link).[1]

[1]Permission to use these unpublished lecture notes for this module was generously granted by the author.

Additional Resources

Archived Pages: 2012 2014 2015 2016 2017

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

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.

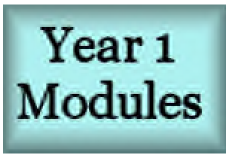
Aims:
To extend the knowledge of first year ODEs with a mixture of applications, modelling and theory to prepare for more advanced modules later on in the course.

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.

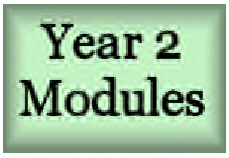
Books:
(Complete Lecture Notes will be made available)
Ordinary Differential Equations and Dynamical Systems, **Gerald Teschl**, [Available online]
Elementary Differential Equations and Boundary Value Problems, **Boyce DiPrima** 1997
Differential Equations, Dynamical Systems, and an Introduction to Chaos,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

Additional Resources

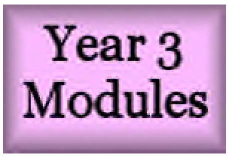
Archived Pages: 2012 2013 2014 2015 2016 2017



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

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

Archived Pages: 2012 2013 2014 2015 2016 2017

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 either MA131 Analysis I or MA137 Mathematical Analysis.

Leads to: ST333 Applied Stochastic Processes.

Commitment: 3 lectures/week, 1 tutorial each in weeks 3, 5, 7 and 9. 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.

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

Deadlines: 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 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

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
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

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 Modules
Year 1 regs and modules
G100 G103 GL11 G1NC

ST222: Games, Decisions and Behaviour

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/st222)
Lecturer(s): **Dr Ric Crossman**

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:

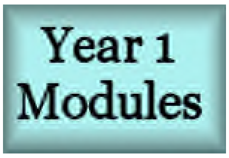
- Students will be familiar with the mathematical and philosophical basis for a number of alternative approaches to probability including subjective probability.
- Students will be familiar with normative decision theory and can apply this to model decision-making in practical examples from a wide range 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:

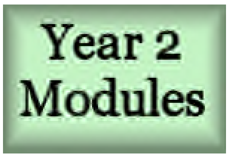
A list with books and website supporting this module will be provided on the resource page for this module. To get a first taste of what the module is about, the following resources may be helpful:

- 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)

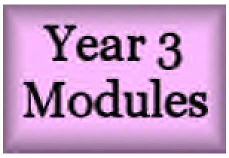
Assessment: Exam (100%)



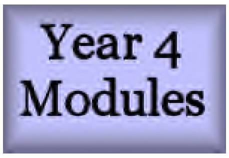
Year 1 regs and modules
G100 G103 GL11 G1NC



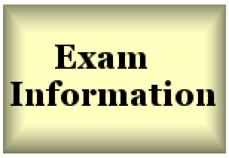
Year 2 regs and modules
G100 G103 GL11 G1NC



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)

277 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, R9L1 - Year 2, R3L4 - Year 2, R4L1 - Year 2, R2L4 - Year 2, R1L4 - Year 2, V7MR - Year 2, V7MP - Year 2, V7MS - Year 2, V7MQ - Year 2, V7MM - 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.

Previous exam papers can be found in the University's past papers archive. Please note that previous exam papers may not have operated under the same exam rubric or assessment weightings as those for the current academic year. The content of past papers may also be different.

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

EC220 & 221 Mathematical Economics I

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

318 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, LA99 - Year 2, LA99 - Year 3, L100 - Year 2, L1L8 - Year 2, L1L8 - Year 3, R9L1 - Year 4, R3L4 - Year 4, R4L1 - Year 4, R2L4 - Year 4, R1L4 - Year 4, V7MP - Year 2, V7MP - Year 3, L1P5 - Year 1, L1PA - Year 1, V7MR - Year 2, V7MR - Year 3, LM1H - 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.

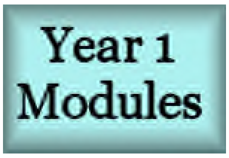
Answer TWO questions ONLY. All questions carry equal weight (50 marks each). Answer each question in a separate booklet.

Approved pocket calculators are allowed.

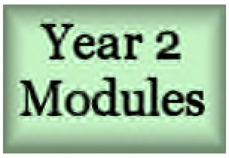
Read carefully the instructions on the answer book provided and make sure that the particulars required are entered on each answer book. If you answer more questions than are required and do not indicate which answers should be ignored, we will mark the requisite number of answers in the order in which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

Previous exam papers can be found in the University's past papers archive. Please note that previous exam papers may not have operated under the same exam rubric or assessment weightings as those for the current academic year. The content of past papers may also be different.

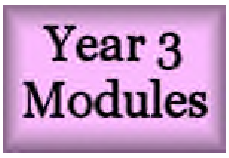
Reading Lists



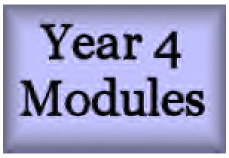
Year 1 regs and modules
G100 G103 GL11 G1NC



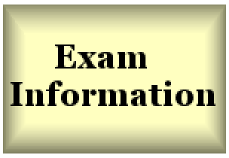
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

EC220 & 221 Mathematical Economics I

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

318 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.
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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.

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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.

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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, LA99 - Year 2, LA99 - Year 3, L100 - Year 2, L1L8 - Year 2, L1L8 - Year 3, R9L1 - Year 4, R3L4 - Year 4, R4L1 - Year 4, R2L4 - Year 4, R1L4 - Year 4, V7MP - Year 2, V7MP - Year 3, L1P5 - Year 1, L1PA - Year 1, V7MR - Year 2, V7MR - Year 3, LM1H - 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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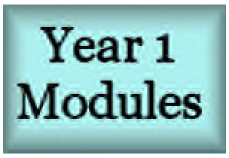
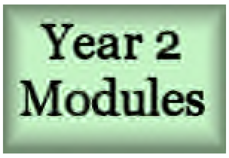
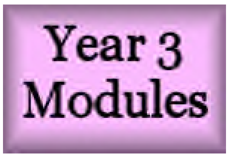
Reading Lists



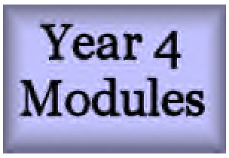
Year 1 regs and modules
G100 G103 GL11 G1NC



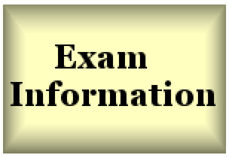
Year 2 regs and modules
G100 G103 GL11 G1NC



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)

459 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, R9L1 - Year 2, R3L4 - Year 2, R4L1 - Year 2, R2L4 - Year 2, R1L4 - Year 2, V7MR - Year 2, GL11 - Year 2, GL12 - Year 2
Optional Module	V7ML - Year 2, V7ML - Year 3, 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, 1 assignment 12 CATS) and in the Autumn and Spring term together 2 x test, 2 x assignments and problem sets 24 CATS)

Assessment

Assessment Method	Coursework (35%) + 3 hour exam (65%)
Coursework Details	One 50 minute test (worth 15%) and one assignment (worth 15%) and problem sets worth (5%)
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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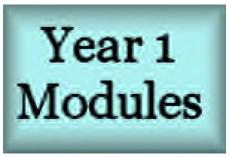
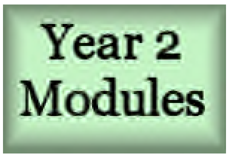
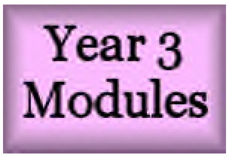
Reading Lists



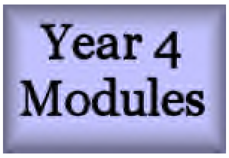
Year 1 regs and modules
G100 G103 GL11 G1NC



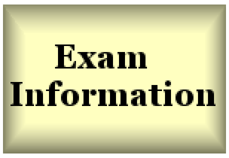
Year 2 regs and modules
G100 G103 GL11 G1NC



Year 3 regs and modules
G100 G103



Year 4 regs and modules
G103



Past Exams
Core module averages

CS242 Formal Specification and Verification

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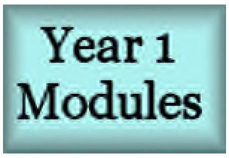
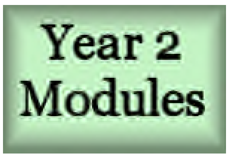
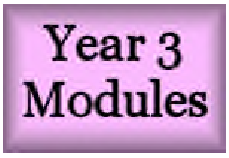


Year 1 regs and modules
G100 G103 GL11 G1NC

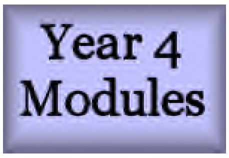


Year 2 regs and modules
G100 G103 GL11 G1NC



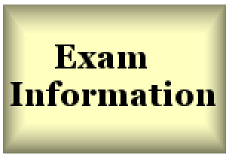
Year 3 regs and modules

G100 G103



Year 4 regs and modules

G103



Past Exams

Core module averages

CS243 Data Structures and Algorithms

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

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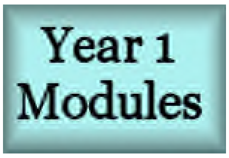
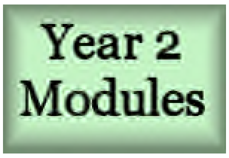


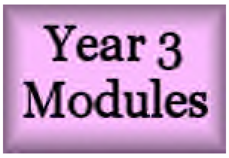
Year 1 regs and modules

G100 G103 GL11 G1NC



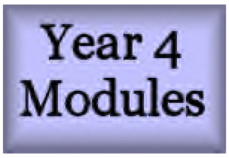
Year 2 regs and modules

G100 G103 GL11 G1NC



Year 3 regs and modules

G100 G103



Year 4 regs and modules

G103

Past Exams

Core module averages

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

Exam Information

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 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

CS254 Algorithmic Graph Theory

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

Note: This module is only available to students in the second year of their degree and is not available as an unusual option to students in other years of study.

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

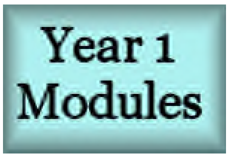
On completion of the module the student shoud be able to:

- 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.

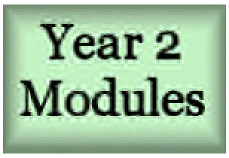
Content

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
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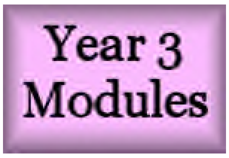
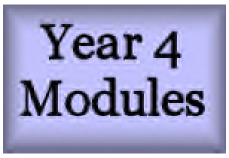
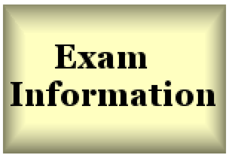


Year 3 regs and modules
G100 G103



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

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Year 2 Modules

Year 2 regs and modules

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Year 3 Modules

Year 3 regs and modules

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Year 4 Modules

Year 4 regs and modules

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Exam Information

Past Exams

Core module averages

CS262 Logic and Verification

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

Note: This module is only available to students in the second year of their degree and is not available as an unusual option to students in other years of study.

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 Modules

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Year 2 Modules

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Year 3 Modules

Year 3 regs and modules
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Year 4 Modules

Year 4 regs and modules
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Exam Information

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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PX262 Quantum Mechanics and its Applications

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

Lecturers: Gavin Bell and Julie Staunton

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 phenomena in particle physics 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. 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. doping. 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. Solution to Dirac for particle in its rest frame and for particles with zero rest mass. 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%).

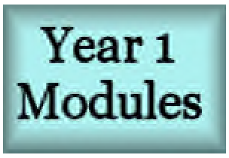
Recommended Text: H D Young and R A Freedman, University Physics, Pearson, AIM Rae, *Quantum Mechanics*, IOP

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 regs and modules
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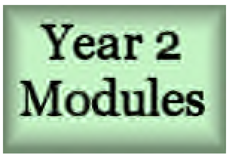

Year 2 regs and modules
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PX263 Electromagnetic Theory and Optics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px263)

Lecturer: Tom Marsh

Weighting: 7.5 CATS

The module develops the ideas of first year electricity and magnetism into Maxwell's theory of electromagnetism. Maxwell's equations pulled the various laws of electricity and magnetism (Faraday's law, Ampere's law, Lenz's law, Gauss's law) into one unified and elegant theory. Establishing a complete theory of electromagnetism has proved to be one the greatest achievements of physics. It was the principal motivation for Einstein to develop special relativity, it has served as the model for subsequent theories of the forces of nature and it has been the basis for all of electronics (radios, telephones, computers, the lot...). The module shows that Maxwell's equations in free space have time-dependent solutions, which turn out to be the familiar electromagnetic waves (light, radio waves, X-rays etc), and studies their behaviour at material boundaries (Fresnel Equations). The module also covers the basics of optical instruments and light sources.

Aims:

The module should study Maxwell's equations and their solutions.

Objectives:

By the end of the module you should:

- understand Maxwell's equations and quantities like the Poynting vector and refractive index
- be able to manipulate these equations in integral or differential form and derive the appropriate boundary conditions at boundaries between linear isotropic materials
- be familiar with plane-wave solutions to these equations in free space, dielectrics and ohmic conductors
- have an understanding of geometrical optics, polarisation of light, the behaviour of light in lenses and prisms, and the properties of different light sources (including lasers)

Syllabus:

Refresher on vector calculus
Ampere's law, Faraday/Lenz's law, Gauss's law in differential form. Need for the displacement current. Statement of Maxwell's equations.
Maxwell equations in vacuum and in matter. Magnetisation and polarization of materials. Relation of E and P, B and M.
Solutions to Maxwell equations in vacuum. Electromagnetic waves, Poynting vector, intrinsic impedance, polarisation.
Boundary conditions. Interfaces between dielectrics, separation into perpendicular and parallel components. Refractive index.
Ohm's law. Interface with a metal, skin effect.
Optics: reflection and refraction. Wavefronts at plane and spherical surfaces. Lenses. Basics of optical instruments, resolution.

Commitment: about 18 Lectures + problems classes

Assessment: 1 hour examination(85%) + assessed work (15%)

This module has a home page.

Recommended Text: IS Grant and WR Phillips, Electromagnetism, Wiley, E Hecht, Optics, H D Young and R A Freedman, University Physics, Pearson also ER Dobbs, Basic Electricity and Magnetism, Chapman and Hall (out of print). R Feynman, Feynman Lectures Vol II, Addison Wesley

Leads from: PX120 Electricity and Magnetism

Leads to: PX384 Electrodynamics

Year 1 Modules

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Year 2 Modules

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Year 3 Modules

Year 3 regs and modules
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Year 4 Modules

Year 4 regs and modules
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Exam Information

Past Exams
Core module averages

PX264 Physics of Fluids

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px264)

Lecturer: Tony Arber

Weighting: 7.5 CATS

The field of fluids is one of the richest and most easily appreciated in physics. Tidal waves, cloud formation and the weather generally are some of the more spectacular phenomena encountered in fluids. The module establishes the basic equations of motion for a fluid - the Navier-Stokes equations - and shows that in many cases they can yield simple and intuitively appealing explanations of fluid flows. The module concentrates on incompressible fluids.

Aims:

The module should explain why PDEs (with associated boundary conditions) are an appropriate model for fluids. To show how physical ideas and limiting cases can help analyse these PDEs which, in general, cannot be solved. These include the role of the Reynolds number, laminar viscous flow, the boundary layer concept and irrotational flow.

Objectives:

At the end of the module you should be able to

- Recognise and write down the equations of motion for incompressible fluids (the Navier- Stokes equations) and understand the origin and physical meaning of the various terms including the boundary conditions
- Derive Poiseuille's formula and understand the conditions for it to be a valid description of fluid flow
- Use dimensional analysis to analyse fluid flows. In particular, you should appreciate the relevance of the Reynolds number.
- Simplify the equations of motion in the case of incompressible irrotational flow and solve them for simple cases including vortices

- Explain the boundary layer concept

Syllabus:

Introduction
Fluids as materials which do not support shear. Idea of a Newtonian fluid. "Plausibility of $\tau = \mu \, \partial u/\partial y$ from assumption of a relaxation time for stress.
Equations of Motion
Hydrostatics: forces due to pressure and gravity. Hydrodynamics: acceleration, continuity and incompressibility. Euler equation.
Streamlined Flow
Streamlines: Integrating Euler for steady flow along a streamline to give Bernoulli. Derivation of Bernoulli via conservation of energy. Applications of Bernoulli: flux through a hole, Pitot-static tube, aerofoil, waves on shallow water.
Hydrodynamics of Viscous Flow
Forces due to viscosity, Navier-Stokes equation. Derivation of Poiseuille's formula for laminar flow between plates.
Turbulence
Laminar flow only one possibility. Turbulent slugs. Need for dimensionless number, Re, Pressure gradient as a function of Re. 2 Regimes: Physical interpretation of Re as Inertial forces/Viscous forces. Poiseuille works when Re small.
Irrotational Flow
Definition of vorticity and circulation. Importance of irrotational flow, Kelvin's circulation theorem.
Examples of irrotational flow: uniform flow, flow past a cylinder. Derivation of lift on thin aerofoil, as example for Magnus Effect.

Circulation around a cylinder. The vortex. Circulation constant round vortex line, need to close or end on surfaces. Advection of unlike vortices. The vortex ring. Circling of like vortices.

Vortices at edges of wings.

Real Flows
Idea of boundary layer; Boundary layer separation and drag crisis.

Commitment: about 18 Lectures

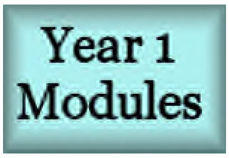
Assessment: 1 hour examination

This module has a home page.

Recommended Texts: DJ Tritton, Physical Fluid Dynamics, OUP; TE Faber Fluid Dynamics for Physicists, CUP

Leads from: PX148 Classical Mechanics and relativity

Leads to: PX350 Weather and the Environment, MA3D1 Fluid Dynamics



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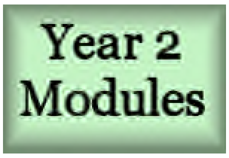

Year 2 regs and modules
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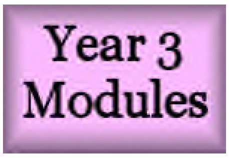

Year 3 regs and modules
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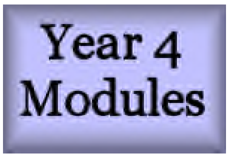

Year 4 regs and modules
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PX266 Geophysics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px266)

Lecturer: Matthew Broome

Weighting: 7.5 CATS

This introductory module describes the behaviour of the solid Earth using physical principles. The topics covered to some extent include: the age of the Earth, plate tectonics, seismology, gravity and the shape of the Earth, oceanic and continental heat, the Earth's core and magnetic field.

Aims:

To present an understanding of the Earth in terms of simple physical principles

Objectives:

The module will develop your understanding of Earth based on the physical principles of radioactivity, gravity, waves, heat and magnetism. You should obtain an overview of the structure of the Earth, of the large-scale processes affecting the Earth, and of the experimental and observational techniques used to probe them.

Syllabus:

1. Introduction. Basic characteristics of Earth: size, shape, mass, structure, age. Earth geometry, spherical co-ordinates
2. Geochronology. Geological time, radiometric dating
3. Gravity. Consequences of spherical geometry, geoid, gravity measurements and anomalies, isostasy and mountain heights
4. Seismology. Types of seismic waves, elasticity and elastic waves, earthquake location and magnitudes, seismology and Earth's interior
5. Plate tectonics. Divergent, convergent and conservative plate boundaries, plate movement on flat earth, rotation poles and present day plate motions, past plate movements, role of Earth's magnetic field
6. Heat. Overview of heat budget and Earth, heat flow and depth of ocean, convection in the mantle, thermal structure of the core, earth's magnetic field.

Commitment: about 18 Lectures

Assessment: 1 hour examination.

This module has a home page.

Recommended Texts: William Lowrie, Fundamentals of Geophysics, CUP; C.M.R Fowler, The Solid Earth - An Introduction to Global Geophysics, CUP

Leads from: 1st year physics modules

Year 4 Modules

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G103

Exam Information

Past Exams
Core module averages

PX267 Hamiltonian Mechanics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px267)

Lecturer: James Lloyd-Hughes

Weighting: 7.5 CATS

This module introduces the Hamiltonian formulation of classical mechanics. This elegant theory has provided the natural framework for several important developments in theoretical physics including quantum mechanics. The module starts by covering the general "spirit" of the theory and then goes on to introduce the details. The module uses a lot of examples. Many of these should be familiar from earlier studies of mechanics while others, which would be much harder to deal with using traditional techniques, can be dealt with quite easily using the language and methods of Hamiltonian mechanics.

Aims:

To revise the key elements of Newtonian mechanics and use this to motivate and then develop Lagrangian and Hamiltonian mechanics

Objectives:

At the end of the module, you should

- Understand the significance of the Lagrangian. You should be able to derive and solve the Euler-Lagrange equations for simple models.
- (Working from the Lagrangian) be able to find the canonical momenta and to construct the Hamiltonian function
- Be able to derive and solve Hamilton's equations for simple systems
- Appreciate the role of (and relations between) constraints, conserved quantities and generalised coordinates

Syllabus:

1. Introduction. Analogy with Optics and constructive interference; principle of least action; examples of L: T-V, -mc2/γ

2. Euler Lagrange Equations. 1-d trajectory, T-V case, worked examples; T+V as a constant of the motion; multiple coordinates with examples

3. Generalised Coordinates and Canonical Momenta. Polar coordinates; angular momentum; moment of inertia of rigid bodies; treatment of constraints; examples

4. Symmetry and Conservation Laws

5. Hamiltonian Formulation. Hamilton's Equations, phase space, examples

6. Normal Modes and Small Oscillations. Inertial and stiffness matrices, diatomic and Triatomic molecules

Commitment: about 18 Lectures

Assessment: 1 hour examination

This module has a home page.

Recommended Text: A good text going well beyond the module is H Goldstein, Classical Mechanics; A helpful reference for the beginning of the module is: Feynmann, Leighton & Sands, The Feynmann Lectures on Physics, Vol 2, Chapter 19

Leads from: PX148 Classical Mechanics and Relativity

Year 1 Modules

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PX268 Stars

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px268)

Lecturer: Don Pollacco

Weighting 7.5 CATS

People have been studying stars for as long as anything else in science. Yet the subject is advancing faster now than almost every other branch of physics. With the arrival of space-based instruments, the prospects are that the field will continue to advance and that some of the most exciting discoveries reported in physics during your lifetime will be in astrophysics.

The module deals with the physics of the observation of stars and with the understanding of their behaviour and properties that the observations lead to. The module covers the main classifications of stars by size, age and distance from the earth and the relationships between them. It also looks at what the observations of stars' behaviour tell us about the evolutionary history of galaxies and of the Universe as a whole.

Aims:

The module should introduce the methods used to measure the distances between stars, their brightness and colour and provide evidence for the large variability of stars found in our Galaxy. It should show how fundamental concepts of physics are used to quantitatively describe the structure and evolution of stars. The module should also explain how observational methods, such as imaging and spectroscopy, can be used to test our understanding of the origin, life, and death of stars.

Objectives:

At the end of the module, you should be able:

- to define the position of a star
- to describe the techniques used to determine their distance from us
- to relate basic quantities such as apparent magnitude, absolute magnitude, flux, luminosity, stellar radius, effective temperature and distance.
- To explain the main characteristics of stellar spectra along the main sequence
- to understand the basic mechanisms of interaction between photons and matter occurring in the atmosphere of a star.
- to understand the basic physical principles necessary to describe the structure and evolution of stars, and to qualitatively describe the birth, life and death of stars.
- to be able to describe the processes of nuclear fusion that powers the light of almost all stars.
- to identify the main features of the Hertzsprung-Russell diagram.

Syllabus:

1. Observational facilities - the optical/IR window - space based astronomy.
2. Coordinate systems: how to define the position of a star. What stars are visible during a night, a month, a year.
3. Trigonometric Parallax. The parsec and parallax angles. Statistical parallax.
4. Fundamental properties of stars - colour, luminosity, apparent and absolute magnitude, stellar radius.
5. Blackbody radiation, thermal equilibrium, effective temperature.
6. Different types of stars - spectral classification - the Harvard spectral classification.
7. Stellar atmospheres - where does the light that we observe originate - interaction between radiation and matter - radiation transfer.
8. The sun: the best observed star. Solar cycle. Magnetic activity.
9. The structure of stars -basic equations - nuclear energy production - mass/radius/luminosity relation - understanding the observed Hertzsprung-Russell diagram
10. Stellar evolution - main sequence life time - from birth to death - young stellar objects, stellar remnants: white dwarfs, neutron stars, black holes.
11. Using stellar populations as test beds for stellar evolution open and globular clusters.
12. Exoplanets: discovery and characteristics. Equilibrium temperature and the habitable zone.

Commitment: about 18 Lectures

The questions on the problem sheets relate principally to the techniques presented in the module and working through them will help you to understand the material. Please feel free to approach me if you have any difficulties with the questions.

Assessment: 1 hour examination

This module has a home page.

Recommended Texts: B.W. Carroll and DA Ostlie, *An Introduction to Modern Astrophysics*, Addison-Wesley; Prialnik, D, *An introduction to the theory of stellar structure and evolution.*, CUP.

Leads to: PX397 Galaxies, PX387 Astrophysics, PX389 Cosmology

Year 1 Modules

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Year 2 Modules

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Year 3 Modules

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Year 4 Modules

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Exam Information

Past Exams
Core module averages

PX269 Galaxies

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px269)

Lecturer: Peter Wheatley

Weighting: 7.5 CATS

Aims:

To illustrate how important physical principles (taught elsewhere in the 1st and 2nd years) can be developed to yield a description of complex physical systems like galaxies. For example the module uses basic ideas from quantum physics, thermodynamics, mechanics and special relativity. The module also tries to illustrate how the same physical laws can be applied in very different situations.

Objectives:

After the module, you should

- Understand the physical principles behind the observational methods used to study galaxies
- Be able to show how observations of (for example) the energy output per unit volume and the widths and intensities of spectral lines may be interpreted to give infomation about galaxies and their constituent parts.
- Be familiar with the standard models for galaxy formation, structure and evolution
- Be aware of some of the outstanding and only partially understood problems in the study of galaxies including the nature of galaxy cores and the role of dark matter

Syllabus:

Brief review of our assumptions about the state of the universe: Olber's Paradox, the Cosmological Principal, General Relativity.

Parameters and Measurement: Distance, Luminosity, Colour Index, the H-R Diagram, stellar clusters, spectroscopy.

Hierarchical structures: stellar clusters, galaxies, clusters, superclusters, walls, voids, filaments and sheets, gravitational lensing.

Spiral galaxy: morphology, constituents (stars, the ISM and ?), size and mass, stellar populations and their dynamics, the LSR, statistical astronomy, simple models.

Classification of Galaxies: The Hubble and other classification schemes, review of galactic types and their structure, elliptical galaxies.

Dark Matter and galactic evolution: Missing gravity (local and general), observation of mass, fundamental particles, baryonic and leptonic dark matter, MACHOS, WIMPS, exotic particles - Axions, topological defects and singularities, stellar mass black holes, cold and hot dark matter.

Exotic galaxies and AGN's: Seyfert galaxies, Starburst galaxies, Quasars - Remote objects, red shift, age of universe

Commitment: about 18 Lectures

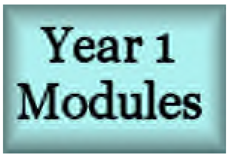
There are a number of handouts which revise or pull together material where this has been taken from other modules. Whilst the Stars option is not a prerequisite for this module, it is useful background for those with no prior knowledge of astrophysics.

Assessment: 1 hour examination.

Recommended Texts: RJ Tayler, Galaxies: structure and evolution, CUP; B Jones, RJA Lambourne and DA Rothery, Images of the Cosmos, The Open University; B Jones, Galaxies, The Open University

Leads from: PX268 Stars

Leads to: PX389 Cosmology and PX387 Astrophysics



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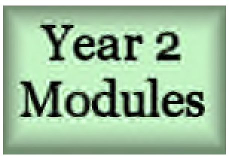

Year 2 regs and modules
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Year 3 Modules

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Year 4 Modules

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Exam Information

Past Exams

Core module averages

PX270 C Programming

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px270)

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Year 1 Modules

Year 1 regs and modules

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Year 2 Modules

Year 2 regs and modules

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Year 3 Modules

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Year 4 Modules

Year 4 regs and modules

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Exam Information

Past Exams

Core module averages

PX272 Global Warming

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px272)

Lecturer: Andrew Levan

Weighting: 7.5 CATS

Aims:

The aim of this module is to introduce you to the challenge posed by: measurements and predictions of climate change,
costing actions and inaction,
the politics of decision and delivery.

Objectives:

At the end of the module you should:

- understand some simple Climate Science.
- appreciate the inherent doubt in making predictions to inform policy.
- appreciate the notion of cost-benefit analysis including major elements of risk.
- be able to engage in political debate as to what to do.
- be acquainted with political obstacles to action

Syllabus:

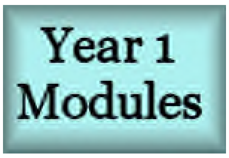
1. The Greenhouse Effect and the main gases responsible. *An essentially qualitative account of why there might be a problem*
2. CO2 production and accumulation. *You will be challenged to work through the key numbers for yourself.*
3. Evidence for Climate Change. *Qualitative survey of what has been measured and whether it is significant*
4. The role of Ice Caps, and sea level rise. *Temperature stabilization by the Triple Point, observed rates of melting and breakup, and the water volumes in question.*
5. Albedo effects. *Ice-caps, deserts, clouds and global dimming.*
6. Estimated hazards to man and Environment. *Warming, sea level rise, changing ocean currents, thermal runaway.*
7. The political response to date. *Kyoto, UK and EU targets.*
8. Available options. *Conservation; Sequestration; Nuclear Energy; Renewable Energy Sources.*
9. Cost-benefit analysis. *Case studies: free market adaptation vs international action*
10. The likelihood of action. *Politics of decisions, prospective winners and losers.*

Commitment: about 10 Lectures and 8 assessed assignments

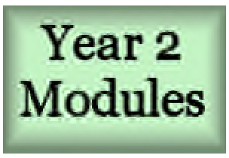
Assessment: The module is 80% examined (1 hour) and 20% assessed.

Recommended Texts:
A good background text is: J (Sir John) Houghton, Global Warming - the complete briefing, CUP 3rd Edition 2004. However there are few relevant up to date printed sources. Instead the internet will be relied upon quite heavily.
This module has its own home page.

Leads to: PX350 Weather and the Environment



Year 1 regs and modules
G100 G103 GL11 G1NC



Year 2 regs and modules
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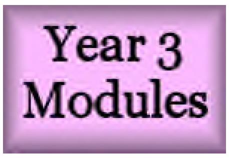

Year 3 regs and modules
G100 G103

PX274 Experimental Particle Physics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px274)

Lecturer: Bill Murray

Weighting: 7.5 CATS

Particle physics experiments are designed to study sub-atomic particles and to test their behaviour against the predictions of the Standard Model (SM). This modules explores how we actually make measurements. It uses the discovery of the Higgs boson at CERN as an example. The major pieces of that important discovery are examined, with more focus on the how and why than the precise quantitative calculation.

The module starts with a brief introduction to particle accelerators, along with the long-lived particles of the Standard Model. The major part of the module describes the interaction of high-energy particles with matter, how this is used in tracking detectors and calorimeters and how these in turn are built into complete experiments which identify particle types, momenta and energies. As the data relating to the events that we want to analyse can be scarce, the module also explains the importance of statistical analysis in the study of such data sets.

Aims:

To explain the methodology of experimental particle physics

Objectives:

At the end of the module you should:

- Understand how experiments studying elementary particles are designed and analysed
- Be able to explain the physical principles limiting such measurements
- Understand the relativistic kinematics of collision events
- Be able to use appropriate statistical techniques to study experimental data

Syllabus:

The common Elementary Particles, and how their interactions are described by Feynman diagrams. Interactions of particles in matter
Particle sources. Artificial sources: Accelerators. Collisions and relativistic kinematics
Physics of particle detectors. Scattering and ionization (including relativistic scattering kinematics). Position, momentum (tracking and decay reaction kinematics) and energy measurements. Particle identification principles
A complete (including statistical) analysis exercise

Commitment: about 18 Lectures

Assessment: 1 hour examination

Recommended Texts:

This module has a home page.

PX276 Methods of Mathematical Physics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px276)

Lecturer: Rudolf Roemer

Weighting: 7.5 CATS

The module starts with the theory of Fourier transforms and the Dirac delta function. Fourier transforms are used to represent functions on the whole real line using linear combinations of sines and cosines. Fourier transforms are a powerful tool in physics and applied mathematics. A Fourier transform will turn a linear differential equation with constant coefficients into a nice algebraic equation which is in general much easier to solve.

The module explains why diffraction patterns in the far-field limit are the Fourier transforms of the "diffracting" object. It then looks at diffraction generally. The case of a repeated pattern of motifs illustrates beautifully one of the most important theorems in the business - the convolution theorem. The diffraction pattern is simply the product of the Fourier transform of the repeated delta functions and the Fourier transform for a single copy of the motif.

The module also introduces Lagrange multipliers, co-ordinate transformations and cartesian tensors illustrating them briefly with examples of their use in physics.

This module is not available to Physics students (F300, F303, F3N1).

Aims:
To teach mathematical techniques needed by second, third and fourth year physics modules.

Objectives:
Students should:

- Be able to represent simple functions in terms of Fourier series and Fourier transforms
- Possess a good understanding of diffraction and interference phenomena
- Be able to minimise/maximise simple functions subject to constraints using Lagrange multipliers
- Be able to express vectors in different coordinate systems, recognise some physical examples of tensors
- Be familiar with the derivation, and with some applications in physical contexts, of Stokes's theorem

Syllabus:
1. **Fourier Series (Revision):**
Representation for function f(x) defined -L to L; brief mention of convergence issues; real and complex forms; differentiation, integration; periodic extensions
2. **Fourier Transforms:**
Fourier series when L tends to infinity. Definition of Fourier transform and standard examples: Gaussian, exponential and Lorentzian. Domains of application: (Time t | frequency w), (Space x | wave vector k). Delta function and properties, Fourier's Theorem. Convolutions, example of instrument

resolution, convolution theorem.

3. **Interference and diffraction phenomena:**
Interference and diffraction: the Huygens-Fresnel principle. Criteria for Fraunhofer and Fresnel diffraction. Fraunhofer diffraction for parallel light. Fourier relationship between an object and its diffraction pattern. Convolution theorem demonstrated by diffraction patterns. Fraunhofer diffraction for single, double and multiple slits. Fraunhofer diffraction at a circular aperture; the Airy disc. Image resolution, the Rayleigh criterion and other resolution limits. Fresnel diffraction, shadow edges and diffraction at a straight edge.

4. **Lagrange Multipliers**
Variation of f(x,y) subject to g(x,y) = constant implies grad f parallel to grad g. Lagrange multipliers. Example of quadratic form.

5. **Vectors and Coordinate Transformations:**
Summation convention, Kronecker delta, permutation symbol and use for representing vector products. Revision of cartesian coordinate transformations. Diagonalizing quadratic forms.

6. **Tensors:**
Physical examples of tensors: mass, current, conductivity, electric field.

Worksheet
7. **Stokes' Theorem**: Line integrals, circulation; curl in Cartesians; statement and proof of Stokes' theorem for triangulations; dependence on region of integration and vector field; gradient, irrotational, solenoidal and incompressible vector fields; applications drawn from electromagnetism, fluid dynamics, condensed matter physics, differential geometry

Commitment: 20 Lectures + 10 Examples Classes

Assessment: 1 hour written examination (80%) + in-class tests/assessed coursework (10%) + 1 worksheet on Stokes's Theorem (10%)

This module has a home page.

Recommended texts: KF Riley, MP Hobson and SJ Bence, *Mathematical Methods for Physics and Engineering: a Comprehensive Guide*, CUP; H D Young and R A Freedman, *University Physics* (11th Edition), Pearson.

Leads to: Second, third and fourth year physics modules.

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

PX277 Computational Physics

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/px277)

Lecturer: Yorck Ramachers

Weighting: 7.5 CATS

This module develops programming in the Python programming language and follows from PX150 Physics Programming Workshop.

Aims:
To acquire programming skills necessary to solve physics problems with the help of the Python programming language, a language widely used by physicists.

Objectives:
Students should:

- Understand how computers can be used to solve physics problems
- Be able to translate physics problems into a form suitable for solution using a computer program
- Be able to design algorithms and implement them
- Be able to handle and analyse physics data.

Syllabus:
1. Handling, processing and analysing physics data: plotting distributions, least square and maximum likelihood fit.
2. Monte Carlo simulation for physics modelling. Different types of random numbers, quality of random number generators. Generation of random numbers according to specific distributions. Brownian motion and diffusion.
3. Numerical integration and differentiation. Mass and centre of mass of object with variable density. Electric fields generated by distributed charge.
4. Numerical solutions of ordinary differential equations. Mechnical oscillations, motion with resistance.

Commitment: 5 lectures and 10 x 1 hour workshops

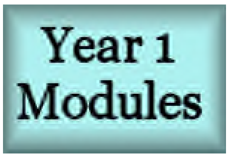
Assessment: 3 assignments

This module has a home page.

Recommended texts: M. Newman, *Computational Physics*, CreateSpace Independent Publishing Platform; H.P. Langtangen, *A Primer on scientific programming with Python*, Springer (e-book).

Leads from: PX150 *Physics Programming Workshop*

Leads to: PX390 *Scientific Programming*



Year 1 regs and modules
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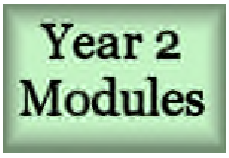

Year 2 regs and modules
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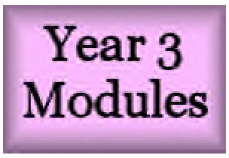

Year 3 regs and modules
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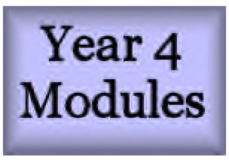

Year 4 regs and modules
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Exam Information

Past Exams

Core module averages

PH201 History of Modern Philosophy

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ph201)

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Year 1 Modules

Year 1 regs and 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

Exam Information

Past Exams

Core module averages

PH210 Logic II Metatheory

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ph210)

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Year 1 Modules

Year 1 regs and 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
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Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages

IE3E1 Introduction to Secondary School Teaching

(https://warwick.ac.uk/fac/sci/maths/undergrad/ughandbook/year2/ie3e1)
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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
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Year 4 Modules

Year 4 regs and modules
G103

Exam Information

Past Exams
Core module averages