University of Leeds
School of Mathematics

Level 2 Modules
2006-7

Enquiries about any of the modules listed in this booklet should be addressed to:

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The School of Mathematics reserves the right to vary the modules it offers in the academic session 2006-7 in the light of changes in staffing or student enrolment, and to make minor changes to module descriptions for academic reasons.

Use of Calculators in Examinations

Students are reminded of our policy that ***only approved basic scientific calculators may be used in examinations for Mathematics modules.***

For the details about which calculators are allowed, please see page 36.

Plagiarism

Plagiarism is defined by the University in the Taught Student Handbook as

"Presenting someone else's work as your own. Work means any intellectual output, and typically includes text, data, images, sound or performance".

The penalties and procedures in cases of alleged plagiarism are set out in the Taught Student Handbook. The penalties include a written warning, a mark of 0 for the work in question and, in extreme cases, exclusion from the University.

The following guidance about plagiarism applies to coursework and projects for Mathematics modules. Other departments provide their own guidance for their modules.

Copying from other students: We encourage students to work together. Many Mathematics students find that working together on problems is beneficial. However, any coursework that you ultimately submit must be your own work even though it may be based on ideas you have shared with other students. So, if you work together, you should write out the solutions you submit separately, in different rooms.

Direct copying from other students is cheating. Students who are found to have copied their work from another student, or who have allowed another student to copy their work, will be regarded as guilty of plagiarism and will be subject to the appropriate penalties.

Quoting from books and the web: In project work, it will sometimes be appropriate to use direct quotations. But if you use direct quotations from books or the web you must indicate clearly which passages are quotations, and you must give an exact reference to where the quotations have been taken from. If you use books or web pages for background information which you then put into your own words, you must indicate this by including a list of your source materials.

Contents

*taught by the Centre for Studies in Science and Mathematics Education, School of Education.

Modules for Joint Honours students

If a module is available to all Joint Honours students this is indicated by including *Joint Honours* in the list of Programmes of Study for the module. Modules restricted to certain divisions of Joint Honours students are listed as *Joint Honours (Arts/ Modern Languages)* or *Joint Honours (Science)* as appropriate.

MATH2011 Real Analysis 2
Semester: 1 Credits: 10 Level: 2
Prerequisites: MATH1035, or equivalent. ***Exclusion: not with MATH 2090***.
Key Topics Assumed: Mathematical induction; definitions of limts, continuity etc from MATH1035 Analysis; Basic Calculus.
Programmes of Study: Mathematics; Mathematics with Finance; Joint Honours (Arts/Modern Languages); Theoretical Physics.

Aims: To develop the ideas introduced in MATH1035 Analysis; to continue to exhibit the notion of rigorous proof; to introduce the ideas of uniformity and change of order in operations involving limits. To enable students to practise writing proofs in a precise form.

Objectives: On completion of this module, students should be able to:
a) use simple ε-δ techniques;
b) use the techniques to determine whether interchanges of two limiting processes are valid;
c) find the limits of simple series of functions and know whether they can be differentiated, or integrated, term-by-term;
d) show that they understand the simpler proofs of theorems used in the module.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes Monitoring of progress: Regular example sheets.

Outline Syllabus: Revision and further results on sequences, series, and on continuous and differentiable functions. Sequences of functions and uniform convergence, with applications to power series. The basic theory of the Riemann integral.

Detailed Syllabus:
1. Taylor's theorem.
2. Further results about the real numbers: Cauchy sequences, the Bolzano-Weierstrass theorem.
3. Series of numbers: conditional convergence, change of order of summation of double series, multiplication of series.
4. Riemann integration. Partitions of an interval, upper and lower sums. Formal properties of the integral. Integrability of monotone and continuous functions. Fundamental Theorem of the calculus. Improper integrals. The integral test for convergence.
5. Sequences and series of functions. Uniform convergence. General principal of uniform convergence. Weierstrass M-test. Term by term integration and differentiation. Applications to power series.

Booklist:
1. M. Hart, Guide to Analysis, 2nd edition, Palgrove, 2001.*
2. W. Clarke, Elementary Mathematical Analysis, 2nd edition, Wadsworth, 1982.
3. M. Spivak, Calculus, Benjamin, World Student Series Edition, 1967.
4. *Classic text-book*: G. H. Hardy, A Course of Pure Mathematics, 10th edition, CUP, 1952.

Informal Description: Students will have developed ideas of formal proofs and the basic notions of real analysis from MATH1035. This module will further develop these ideas to establish the classical foundations of the theory of functions and the calculus on a secure basis. This is a central module for the understanding of modern mathematics, and is an essential or desirable prerequisite for many other modules in all branches of the subject. Not all functions in mathematics are given by combinations of simple formulas. This module investigates precise conditions under which more general functions can be differentiated or integrated, and explores when the order of two limiting operations can be interchanged. Two of the striking theorems proved are Taylor's theorem and the fundamental theorem of the calculus.
Assessment: 85% 2-hour written examination at end of semester; 15% in-course tests.

MATH2021 Complex Analysis
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH 2011, or equivalent. ***Exclusion - not with MATH 2090***.
Key Topics Assumed: Complex numbers. Sequence and series. Continuous functions.
Programmes of Study: Mathematics; Mathematics with Finance; Joint Honours (Arts/Modern Languages); Theoretical Physics.

Aims: General introduction to complex analysis, which is central to Pure Mathematics, with applications relevant in Applied Mathematics.

Objectives: On completion of this module, students should be able to:
a) use the Cauchy-Riemann equations to decide where a given function is analytic;
b) compute the harmonic conjugates of typical harmonic functions;
c) determine the radius of convergence of complex power series;
d) compute standard contour integrals using the fundamental theorem of the calculus, Cauchy's theorem or Cauchy's integral formula;
e) classify the singularities of analytic functions and to compute, in the case of a pole, its order and residue;
f) evaluate typical definite integrals by using the calculus of residues.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Complex sequences and series; continuous and analytic functions; contour integration; Cauchy's theorem; Cauchy's integral formula; Taylor series; the calculus of residues for evaluating definite integrals.

Detailed Syllabus:
1. Complex sequences and series. Convergence of sequences and series. Complex exponential and logarithm.
2. Differentiable functions. Open sets in **C**. Continuous functions on open sets. Differentiability. Cauchy-Riemann equations. Harmonic functions. Power series and radius of convergence.
3. Contour integration. Definitions of contours and closed contours. Integrals of continuous functions along a contour. Estimates for integrals. Fundamental theorem of the calculus for analytic functions.
4. Cauchy's theorem and integral formula. Winding number. Cauchy's theorem Cauchy's integral formula. Liouville's theorem.
5. Taylor's theorem. Formula for coefficients in complex Taylor series. Differentiable functions are infinitely differentiable.
6. Calculus of residues. Definitions of pole of order m, simple pole, removable singularity, essential singularity, residue. Cauchy's residue theorem. Application to calculation of definite integrals.

Booklist:
1. I. Stewart and D. Tall, Complex Analysis, Cambridge University Press, 1983.
2. G.J.O. Jameson, A First Course on Complex Functions, Chapman and Hall, 1970.
3. H.Priestley, Introduction to Complex Analysis, Oxford University Press, 1990.
4. A.F. Beardon, Complex Analysis, John Wiley, 1979.

Informal Description: Complex analysis was the great triumph of nineteenth century mathematics. The work of the French mathematician Cauchy laid the foundations for many deep results and applications to other branches of mathematics. The latter part of this course is an exposition of Cauchy's beautiful and surprising theorems about analytic functions. One such result enables us to use integration in the complex plane to calculate definite integrals which apparently do not involve the complex numbers at all!

Assessment: 100% 2 hour written examination at end of semester.

MATH2032 Rings, Polynomials and Fields
Semester: 2 Number of credits: 10 Level: 2
Prerequisites: MATH1022 and (MATH1015 or MATH1060), or equivalent.
Programmes of study: Mathematics BSc and MMath; Mathematical Studies, Joint Honours (Arts/Modern Languages).

Aims: To extend the students' understanding of major examples of fields and rings, setting them in an axiomatic context.

Objectives: On completion of this module the student should be able to:
a) State the axioms of a ring and deduce directly from them basic properties;
b) Identify units and irreducibles in various examples, using appropriate tests;
c) Demonstrate understanding of unique factorisation or lack of it;
d) State the axioms of a field and deduce properties of extension fields;
e) Use minimal polynomials and the tower law when dealing with extension fields;
f) Apply the theory of fields to solve problems about ruler and compass constructions.

Methods of teaching: Hours: Lectures 22, Tutorials 0, Practicals 0.
Other hours: 11 Examples classes. Monitoring of progress: examples sheets.

Outline syllabus: Basic theory of rings, especially integers and quadratic extensions, and polynomials over $\mathbb{Z}$ or over a field. Irreducible elements and factorisation. Basic theory of finite field extensions with application to ruler and compass constructibility.

Detailed syllabus:
1. Euclid's Algorithm. Fundamental Theorem of Arithmetic.
2. The notion of a ring.
3. Zero-divisors, units and associates.
4. Polynomials over a field.
5. Divisibility in integral domains.
6. Uniqueness of factorisation.
7. Polynomials over the integers.
8. Field extensions.
9. Algebraic elements.
10. Ruler and compass constructions.

Booklist:
1. R.B.J.T. Allenby. Rings, Fields and Groups, 2nd edition, Butterworth-Heinemann, 1991.*
2. I. Stewart, Galois Theory, 3rd edition, CRC/Chapman & Hall, 2003. (Chapters 1 - 6 only).
3. I.N. Herstein. Abstract Algebra, 3rd edition, John Wiley and Sons, 1999.

Informal Description: A *ring* is an algebraic system in which addition, subtraction and multiplication may be performed. Integers, polynomials and matrices all provide examples of rings, so this notion covers an important range of mathematical structures. They are studied in this module. The ideas are used to prove the theorem that there is no straight-edge and compass construction for trisecting a general angle.

Assessment: 100% 2-hour written examination.

MATH2040 Mathematical Logic 1
Semester: 1 Credits: 10 Level: 2
Prerequisites: None
Key Topics Assumed: Mathematical induction. Natural and real numbers.
Programmes of Study: Mathematics, Joint Honours; Computer Studies; Philosophy.

Aims: To describe the fundamental notions of mathematical logic, including the distinction between syntax and semantics. To present a proof of the completeness theorem in the propositional case and introduce a first order predicate calculus.

Objectives: On completion of this module, students should be able to:
a) express logical arguments in a formal language, and thereby to analyze their correctness;
b) find disjunctive normal form for a propositional formula and prenex normal form for a first order formula;
c) distinguish between syntax and semantics, and give simple formal proofs in a natural deduction system.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Syntax and semantics in mathematical logic. Propositional logic. Semantics via truth tables. Boolean algebras. Natural deduction proof system. Completeness and compactness theorems. Introduction to predicate logic.

Detailed Syllabus:
1. Propositional Calculus; Semantics. Notion of formula (well-formed formula). Algorithms for parsing expressions. Syntax of a standard propositional calculus. Semantics via truth-tables. The notion of semantic (logical) consequence. Tautologies, contradictions, satisfiability, models. Disjunctive and conjunctive normal form. Finite Boolean algebras.
2. Formal Proofs. Formal proofs in a natural deduction proof system. Deductions and theorems. Soundness. A proof of the completeness of propositional logic. Decidability of satisfiability. Use of propositional logic to formalize everyday reasoning.
3. Predicate Logic. Introduction to predicate logic. The notion of a first order structure and Tarski's definition of truth. Manipulations of the quantifiers and prenex form. Formal proofs in predicate logic.

Booklist:
1. J. Barwise and J.Etchemendy, The Language of First Order Logic, CSLI Publications, 1995.
2. J. K. Truss, Discrete Mathematics for Computer Scientists, Addison-Wesley, 2nd edition, 1998*.
3. D. van Dalen, Logic and Structure, Springer-Verlag, 3rd edition, 1997.
4. A. G. Hamilton, Logic for Mathematicians, CUP, revised edition, 1988.
5. R. R. Stoll, Sets, Logic, and Axiomatic Theories, Freeman, 2nd edition, 1974.

Informal Description:
Mathematical logic means both the mathematics of logic, that is, the mathematical study of all forms of reasoning, and also the logic of mathematics, that is studying the particular methods of reasoning used in mathematics. The common approach is to focus attention on the language which is used to express arguments, and study formal languages whose syntax is precisely defined.

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MATH2040 Mathematical Logic 1 *continued*

Mathematical logic is useful because it throws light on mathematics itself, and because it can be applied to problems in philosophy, linguistics, and other areas. In recent times some fruitful applications of logic have been to theoretical computer science. This should not deter those who do not like practical computing. Indeed, one of the main achievements of mathematical logic has been to prove that there are precisely defined mathematical problems that computers cannot solve - a comforting thought. This module is an introduction to mathematical logic and will concentrate on the definition of formal languages which can be used to express mathematical ideas, leaving many of the topics just mentioned for further development in later modules.

The homework will count towards the final grade and is an essential part of the course.

Assessment: 85% 2-hour written examination at end of semester, 15% coursework.

MATH2051 Geometry of Curves and Surfaces
Semester: 1 Credits: 10 Level 2
Prerequisites: Calculus (MATH1050 or MATH1932 or MATH1960+MATH1970) and Linear Algebra (MATH 1015 or MATH1060 or MATH1331) or equivalents.
Key Topics Assumed: Partial derivatives, 1st order ODEs, scalar and vector products, linear algebra (including eigenvalues and eigenvectors), hyperbolic functions.
Programmes of Study: Mathematics; Mathematical Studies; Joint Honours; Theoretical Physics.

Aims: To introduce students to the geometry of curves and surfaces in *n*-dimensional Euclidean space, focusing mainly on the cases $n = 2$ and $n = 3$. To develop students' geometrical intuition. To show how familiar techniques of multivariable calculus and linear algebra can be used to measure geometric quantities.

Objectives: On completion of this module, students should be able to:
a) Recognise a regularly parametrized curve and compute its arc length and curvature.
b) Construct and manipulate the Frenet frame of a curve in $\mathbf{R}^3$.
c) Construct the tangent and normal spaces of a parametrized surface.
d) Compute the shape operator of an oriented hypersurface, and manipulate it to find the associated curvatures of the hypersurface.
e) Construct simple minimal surfaces, and surfaces of prescribed Gaussian curvature.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of Progress: Regular problem sheets

Outline Syllabus: Parametrized curves in Euclidean space, their arc length and curvature, evolutes and involutes, the Frenet formulas. Parametrized surfaces, their tangent and normal spaces, geodesics. The shape operator on an oriented hypersurface and associated curvatures. Minimal surfaces, surfaces of prescribed Gaussian curvature and surfaces of revolution in $\mathbf{R}^3$.

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Detailed Syllabus: The topics covered are:

1. Parametrized curves in $\mathbf{R}^n$, reparametrization, arc length.
2. Curvature of curves in $\mathbf{R}^n$, signed curvature of curves in $\mathbf{R}^2$, evolutes and involutes of planar curves, the Frenet formulae for curves in $\mathbf{R}^3$.
3. Parametrized surfaces in $\mathbf{R}^3$, and surfaces of revolution.
4. The tangent and normal spaces of a parametrized surface. Oriented hypersurfaces. Directional derivatives.
5. The shape operator of an oriented hypersurface: principal, Gauss and mean curvatures.
6. Minimal surfaces and surfaces of prescribed Gaussian curvature

Booklist:

1. J. Oprea, Differential Geometry and its Applications, Prentice-Hall 1997.
2. M.P. do Carmo, Differential Geometry of Curves and Surfaces, Prentice-Hall, 1976.

Informal description:

Differential geometry has played a central and influential role in the development of 20th century pure mathematics and is fundamental to our understanding of the natural world. It is a key element of modern theories of particle physics and cosmology, and a crucial ingredient of all advanced approaches to mechanics and dynamical systems theory. This course offers an introduction to the subject by examining the geometry of curves and higher dimensional surfaces embedded in Euclidean space. The approach is to use familiar ideas from multivariable calculus and linear algebra to construct and study geometric objects, with elegant abstract definitions being illustrated by many concrete examples.

Assessment: 85% 2-hour written examination at end of semester, 15% in-course test.

MATH2080 Further Linear Algebra

Semester: 1 Credits: 10 Level: 2

Prerequisites: MATH1015 or MATH 1060, or equivalent.

Exclusion - not with MATH 2200.

Key Topics Assumed: Solution of linear equations, Matrix algebra and reduction to echelon or row-reduced form. Evaluation of determinants and finding of eigenvalues (in simple cases) and eigenvectors. A first look at linear independence and spanning.

Programmes of Study: Mathematical Studies; Joint Honours.

Aims: To introduce the idea of linear transformation and some of its applications, and to develop sufficient theory, e.g. diagonalization, for applications in Pure and Applied Mathematics and Statistics.

Objectives: On completion of this module, students should be able to reproduce the appropriate definitions accurately, reproduce short proofs that they have seen in the module and do examples on the material which are more challenging than those at level 1.

Methods of teaching: Hours: Lectures: 22 Examples classes: 10. Monitoring of progress: Regular example sheets.

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Outline Syllabus: Linear transformations, matrix representation of a linear transformation, equivalent matrices, similar matrices, Jordan canonical form, inner-product spaces.

Detailed Syllabus:
1. Revision of vector spaces and subspaces, including axioms for vector spaces over the real numbers, the complex numbers and the field of two elements. Revision of linear dependence and independence. Spanning sets and bases, definition of a linear transformation.
2. Image and kernel of a linear transformation.
3. Linear transformations and matrices: By taking bases of V and W, a linear transformation from V to W corresponds to a matrix. Equivalence, canonical form under equivalence.
4. Case when V=W: similarity.
5. For vector spaces over R or C, revision of eigenvalues, eigenvectors characteristic equation. Jordan canonical form, Cayley Hamilton Theorem, Minimum polynomial.
6. Inner products and Euclidean spaces. Orthogonal vectors and the Gram-Schmidt process. Isometry and orthogonal matrices.

Booklist:
1. S. Lipschutz, Schaum's Outline of Linear Algebra, McGraw-Hill, 3rd edition, 2000.
2. S. I. Grossman, Elementary Linear Algebra, 5th Edition, Saunders College Publishing, 1994.

Informal Description: This course carries on from Linear Algebra, MATH1060, and develops the more abstract ideas of vector spaces and linear transformations. These ideas are then applied to questions about changing bases, so that the matrices become as simple as possible.

Assessment: 85% 2-hour written examination at end of semester, 15% coursework.

MATH2090 Real and Complex Analysis

Semester: 2 Credits: 10 Level 2
Prerequisites: MATH1035 or MATH 1050, or equivalent.
Exclusion - not with MATH 2011, MATH 2021.
Key Topics Assumed: Calculus and Mathematical Analysis.
Programmes of Study: Mathematics; Mathematical Studies; Joint Honours; Mathematical Engineering.

Aims: To deepen the understanding of ideas based on limits. To introduce the basic ideas of complex analysis. To show that many ideas of analysis, such as convergence of series, have their most natural setting in the complex plane, and to illustrate the application of these ideas to problems in real analysis.

Objectives: On completion of this module, students should be able to:
a) make simple arguments concerning limits of real-valued functions; show continuity and differentiability in real-valued functions; and make simple uses of these;
b) calculate Taylor and Laurent expansions and use the calculus of residues to evaluate integrals.

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MATH2090 Real and Complex Analysis *continued*

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Continuity and differentiability in real analysis. Complex functions, continuity, differentiability. Contour integration. Cauchy's Theorems. Taylor and Laurent series. Applications of the residue calculus.

Detailed Syllabus:
1. Real Analysis Improper integrals (infinite range only); limits, continuity and differentiability of functions of a real variable.
2. Basic ideas of complex function theory. Limits, continuity, analytic functions, Cauchy-Riemann equations.
3. Contour integrals. Cauchy's theorem, Cauchy's integral formula.
4. Power series. Analytic functions represented as Taylor or Laurent series.
5. Singularities. Orders of poles, Cauchy's residue theorem, evaluation of definite integrals.

Booklist:
1. M.Hart, Guide to Analysis, Palgrave, 2001.
2. I. Stewart and D. Tall, Complex Analysis: (the Hitchhiker's guide to the plane), CUP, 1983

Informal Description: Complex analysis was the great triumph of nineteenth century mathematics. The results of the French mathematician Cauchy laid the foundations for many deep results and applications to other branches of mathematics. The latter part of this course is an exposition of Cauchy's beautiful and surprising theorems about analytic functions. One such result enables us to use integration in the complex plane to calculate definite integrals which apparently do not involve the complex numbers at all! The first part of the course does some necessary spadework, deepening and extending ideas and results about continuity and differentiability of real-valued functions.
Assessment: 85% 2-hour written examination at end of semester, 15% coursework.

MATH2200 Linear Algebra 2
Semester: 1 Credits: 10 Level: 2
Key Topics Assumed: Basic concepts of Linear Algebra.
Prerequisites: MATH1015 or MATH1060 or MATH 1331, or equivalent.
Exclusion - not with MATH 2080.
Programmes of Study: Mathematics; Mathematics with Finance; Theoretical Physics; Joint Honours (Arts/Modern Languages).

Aims: To develop the concept of linear transformation met in Linear Algebra 1 (MATH 1015), to consider how different matrices can arise from a single linear transformation and to develop methods for finding the simplest such matrix.

Objectives: On completion of this module, students should be able to:
a) represent a linear transformation by a matrix with respect to a given basis;
b) determine whether a matrix is diagonalisable and calculate its invariants such as the minimum polynomial;
c) perform standard calculations in real inner product spaces, including the Gram-Schmidt process;
d) diagonalise a quadratic form and determine its rank and signature.

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MATH2200 Linear Algebra 2 *continued*

Methods of teaching:
Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus:
Linear transformations, choice of bases giving a matrix representation of a linear transformation, the effect of changing bases, similar matrices, Cayley-Hamilton theorem, inner products and Euclidean spaces, introduction to quadratic forms and diagonalisation.

Detailed Syllabus:
1. Revision of vector spaces, subspaces, bases and dimensions.
2. Linear transformations and representation of a linear transformation by a matrix. The AP = PB theorem.
3. Diagonalisation of a matrix. Triangular matrices, Cayley-Hamilton theorem and the minimum polynomial of a matrix.
4. Inner product and Euclidean spaces, orthogonal vectors and the Gram-Schmidt process.
5. Quadratic forms and diagonalisation of real and symmetric matrices.

Booklist:
1. S. Lipschutz, Linear Algebra Schaum Outlines, 4th edition, McGraw-Hill, 1991.
2. S. I. Grossman, Elementary Linear Algebra, 4th edition, Saunders, 1991.

Informal Description:
This module carries on from Linear Algebra 1 (MATH1015) and develops the concept of a linear transformation on an abstract vector space. These ideas are then applied to questions about ‘changing variables’ so as to obtain the simplest form of a matrix or a quadratic form.

Assessment: 85% 2-hour written examination at end of semester, 15% coursework.

MATH2210 Introduction to Discrete Mathematics
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH1015 or MATH1060, or MATH1331 or equivalent.
Key Topics Assumed: A-level Algebra.
Programmes of Study: Mathematics; Mathematical Studies; Mathematics with Finance; Joint Honours.

Aims: To introduce students to combinatorial thinking, and to demonstrate the wide range of applications.

Objectives: On completion of this module, students should be able to:
a) solve counting problems involving permutations, combinations and the Inclusion-Exclusion principle; b) formulate counting problems as linear recurrence relations, and solve linear recurrence relations; c) test a graph to determine whether it is connected d) use Kruskal’s algorithm to find minimal connectors; e) in simple cases, determine whether or not a graph is planar; f) prove and apply Euler’s formula for planar graphs; g) devise register machine programs for simple functions; h) prove the closure properties of the class of computable functions; i) prove that the Halting Problem is computably insoluble.

Methods of teaching: ours: Lectures: 22 Tutorials: 0 Practicals 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

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Outline Syllabus:
Combinatorial enumeration problems. Basic concepts of Graph Theory. Computability: algorithms and undecidable problems.

Detailed Syllabus:
1. Combinatorial Enumeration Problems: Permutations and combinations. The inclusion-exclusion principle. Recurrence relations.
2. Introductory Graph Theory: Basic definitions. Connected graphs. Eulerian graphs. Kruskal's algorithm for minimal connectors. Planar graphs. Euler's formula for planar graphs.
3. Computability: algorithms and undecidable problems. Register Machines. Closure properties of register machine-computable functions. Recursive functions. The Halting Problem.

Booklist:
1. S.B.Cooper, Computability Theory, Chapman & Hall/CRC, 2004.
2. A. B.Slomson, An Introduction to Combinatorics, Chapman & Hall, 1997.
3. J. K. Truss, Discrete Mathematics for Computer Scientists, 2nd edition, Addison-Wesley, 1998.
4. R. J. Wilson, Introduction to Graph Theory, 4th edition, Longman, 1996.

Informal Description:
Discrete mathematics deals with finite mathematical structures. It has its own flavour distinct from that of geometrical, algebraic and analytical mathematics which usually concerns itself with infinite structures. This module introduces some of the key ideas in three different areas of discrete mathematics.
Combinatorial enumeration deals with problems such as: How many poker hands are there of each type? They range from very easy to extremely difficult problems. We describe some of the more straightforward methods for solving problems of this kind.
Graph theory is an important mathematical tool in such different areas as linguistics, chemistry and, especially, operational research. But its origins are in the mathematical puzzles such as that of the Bridges of Königsberg, and Graph Theory continues to have its own intellectual appeal apart from its practical applications.
Computability deals with fundamental questions about what problems computers can, in principle, solve. With origins in Mathematical Logic and philosophy, the Theory of Computability has grown into an important area of modern theoretical research underpinning the design and analysis of algorithms in computer science, and contributing to our understanding of the role of incomputability in mathematics and the physical universe. We study a theoretical model of computation, a Register Machine, which enables us to develop a machine independent theory of algorithms.

Assessment: 100% 2-hour written examination.

MATH2360 Vector Calculus
Semester: 1 Credits: 10 Level: 2
Prerequisites: Calculus (MATH 1932 or MATH1960) and Linear Algebra (MATH 1011), or equivalent
Exclusion: Not with MATH 2420.
Key Topics Assumed: Vectors. Basic Calculus. Determinants. Partial derivatives.
Programmes of Study: Mathematics; Theoretical Physics.

Aims: To provide students with the mathematical techniques of vector calculus required to differentiate vector and scalar fields. To enable students to perform integrals of vector and scalar functions over lines, surfaces and volumes in various coordinate systems.

Objectives: On completion of this module, students should be able to:
a) calculate vector and scalar derivatives of vector and scalar fields using the grad, div and curl operators;
b) use suffix notation to manipulate Cartesian vectors and their derivatives;
c) calculate multiple integrals in two and three dimensions including changing variables using Jacobians;
d) calculate line and surface integrals and use the various integral theorems.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Multiple integrals. Vector calculus (grad, div and curl); divergence and Stokes' theorems.

Detailed Syllabus:
1. Vector Calculus: grad, div, curl and the ∇ operator. The directional derivative and Laplacian operators.
2. Suffix notation: representation of vectors and their products using suffix notation. The Kronecker delta and alternating tensors. Grad, div and curl in suffix notation. Use of suffix notation to manipulate products and combinations of vector differentials.
3. Double and triple integrals of scalars. Change of order of integration for double integrals over non-rectangular domains. Transformation of coordinates: the Jacobian. Cylindrical and spherical polar coordinates.
4. Scalar line and surface integrals of vectors in 3 dimensional space. Parameterisation of lines and surfaces, tangent and normal vectors. Evaluation of line and surface integrals. Other forms of line and surface integrals.
5. Exact differentials and conservative fields. The divergence and Stokes' theorems.
6. Orthogonal curvilinear coordinates. Grad, div and curl in cylindrical and spherical polar coordinates.

Booklist:
1. P.C.Mathews, Vector Calculus (SUMS series), Springer, 1998.*
2. M. R. Spiegel, Vector Analysis (Schaum Series), McGraw-Hill, 1974.
3. W.Cox, Vector Calculus, Arnold, 1998.

Informal Description: Vector calculus is the extension of ordinary one-dimensional differential and integral calculus to higher dimensions. As such it provides the mathematical framework for the study of a wide variety of physical systems, such as fluid mechanics and electromagnetism that can be described by vector and scalar fields.

Assessment: 85% 2 hour written examination at end of semester, 15% coursework.

MATH2370 Linear Differential Equations and Transforms
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH 2360, or equivalent. ***Exclusion: Not with MATH 2431***.
Key Topics Assumed: Basic Calculus in one and several variables. Taylor's theorem, series, ODEs, eigenvectors and eigenvalues of matrices.
Programmes of Study: Mathematics; Theoretical Physics.

Aims: To describe the method of separation of variables for the solution of PDEs subject to given boundary conditions, incorporating such topics as power series solution of ODEs, orthogonality of eigenfunctions of symmetric operators, and the basic properties of Bessel and Legendre functions. To introduce Fourier and Laplace transforms and apply them to various linear boundary and initial value problems.
Objectives: On completion of this module, students should be able to:
a) obtain power series solutions of 2nd order homogeneous linear ODEs;
b) test 2nd order linear differential operators for symmetry and draw appropriate conclusions from the resulting orthogonality of their eigenfunctions;
c) solve the standard PDEs of mathematical physics in Cartesian or (2D or 3D) polar coordinates subject to given boundary conditions by the method of separation of variables, using Bessel and Legendre functions where necessary;
d) use Fourier and Laplace transforms to solve a range of boundary and initial value problems for linear ODEs and PDEs.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practical: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: The method of separation of variables and its ramifications, Fourier and Laplace transforms with applications.

Detailed Syllabus: Separation of variables, power series solution of ODEs, symmetric operators and orthogonality of eigenfunctions, Bessel and Legendre functions, their basic properties and application to boundary and initial value problems. Fourier and Laplace transforms, with applications to boundary and initial value problems.

Booklist:
1. M. A. Pinsky, Partial Differential Equations and Boundary Value Problems, McGraw-Hill Education, 1991 and 1997.
2. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, Wiley, 6th Edition, 1997.

Informal Description:
This module introduces a variety of techniques for the solution, subject to suitable boundary and initial conditions, of the basic PDEs of mathematical physics, which describe such ubiquitous phenomena as waves and diffusion, as well as the potential problems of gravitation, electromagnetism and fluid dynamics. The method of separation of variables leads to the solution of various linear ODEs with variable coefficients by the method of power series. The solutions can be viewed as eigenfunctions of symmetric operators, and consequently possess orthogonality properties analogous to those of the eigenvectors of a real symmetric matrix. The particular cases of the Bessel functions and the Legendre polynomials are considered in some detail and applied to the solution of various boundary value problems. The module ends with a section on Fourier and Laplace transforms. These can be used to convert a problem involving an infinite space or time domain into a new and simpler problem. One then solves the simpler problem and converts back to obtain the solution to the original problem.

Assessment: 85% 2-hour written examination at end of semester, 15% coursework.

MATH2391 Nonlinear Differential Equations
Semester: 2; Credits: 10; Level: 2
Prerequisites: MATH1932 or MATH1960 or MATH1970 or MATH1400 or MATH2450 or equivalent. (MATH 2360 or MATH 2420 recommended but not essential.)
Key topics assumed: Curve sketching. eigenvalues and eigenvectors, Taylor series in two variables. It will be helpful but not essential to have used MAPLE before.
Programmes of Study: Mathematics; Mathematical Studies; Mathematics with Finance; Joint Honours (Science); Theoretical Physics; Geophysical Science.

Aims: The aim of this course is to present an introduction to Nonlinear Dynamics and Dynamical Systems, in the context of first and second order autonomous nonlinear ordinary differential equations (ODEs), including equilibrium states, periodic orbits and elementary bifurcation theory. Some applications will be included, with the aim of displaying the usefulness of the theory.

Objectives: On completing this module, students should be able to:
a) sketch phase plane portraits of second-order linear and nonlinear ODEs.
b) sketch bifurcation diagrams and identify bifurcation points.
c) determine the stability of equilibrium points using a variety of methods.
d) determine the existence or otherwise of periodic orbits in second order autonomous nonlinear ODEs using Dulac's criterion, Lyapunov functions and the Poincaré-Bendixson Theorem.

Method of teaching: Hours: Lectures: 22; Tutorials: 0; Practicals: 0; Examples Classes: 11. Monitoring of progress: regular examples sheets.

Outline syllabus: Existence and uniqueness of solutions. First order nonlinear ODEs. Bifurcations in first order nonlinear ODEs. Second order linear ODEs: the exponential matrix and phase portraits. Linear stability theory. Second order nonlinear ODEs. Qualitative study of periodic solutions. Dulac's criterion, Lyapunov functions, Poincaré index theory, Poincaré-Bendixson Theorem.

Detailed syllabus
1. Existence and uniqueness of solutions of ordinary differential equations. Examples of finite time blow-up and non-uniqueness of solutions.
2. First order nonlinear ODEs. Stability of equilibrium solutions. Interpretation of the nonlinear ODE as a vector field.
3. Bifurcation theory for first order nonlinear ODEs: the saddle-node, transcritical and pitchfork bifurcations. Discussion of structural stability.
4. Second order linear ODEs. Phase portraits. Construction of the exponential matrix, including Jordan canonical form for 2×2 matrices.
5. Second order nonlinear ODEs. Equilibrium solutions and linear stability theory. Using MAPLE to assist drawing phase portraits.
6. Elementary theory of periodic orbits. Dulac's criterion, Lyapunov functions, Poincaré index theory, Poincaré-Bendixson Theorem.
7. Bifurcations in second order nonlinear ODEs: the Hopf bifurcation. Only treated as a statement, without proof or extended study.

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MATH2391: Nonlinear Differential Equations *continued*

Booklist

1.S.H.Strogatzm, Nonlinear Dynamics and Chaos,Westview Press 1994 (Primary reference for this module)
2. D.S.Jones and B.D.Sleeman, Differential Equations and Mathematical Biology, CRC, 2003
3. F.Verhulst, Nonlinear Differential Equations and Dynamical Systems, Springer, 1985
4. R.Grimshaw, Nonlinear Ordinary Differential Equations, Blackwell, 1990
5. P.Glendinning, Stability, Instability and Chaos, Cambridge UniversityPress, 1994
6. P.Drazin, Nonlinear Systems, Cambridge University Press, 1992
7. Y.A.Kuznetsov, Elements of Applied Bifurcation Theory, second edition, Springer, 1998
8. J.Guckenheimer and P.Holmes, Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields, Springer, 1983 (reprinted with corrections 1986)
9. D.K.Arrowsmith and C.M.Place, Introduction to Dynamical Systems, Cambridge University Press, 1990

Informal description:
Nonlinear systems occur widely in the real world, and may produce oscillations or even wild chaotic fluctuations even when influenced by a constant external force. This course provides a first introduction to the mathematics behind such behaviour.

Assessment 80% 2-hour written exam at end of semester; 10% coursework; 10% in-course tests.

MATH2410 Special Relativity
Semester: 1 Credits: 10 Level: 2
Prerequisites: (MATH1015 or MATH1060 or MATH2450) and (MATH1932 or MATH1960 or MATH1050) and (MATH1382 or MATH1410), or equivalent.
Key Topics Assumed: Single variable differential calculus; matrix algebra and determinants; 3D vector algebra; basic mechanics.
Programmes of Study: Mathematics; Mathematical Studies; Joint Honours (Science); Theoretical Physics; Geophysical Sciences.

Aims: To introduce students to the concept of the relativity of motion and to the physical and mathematical principles of the Special theory of Relativity.

Objectives: On completion of this module, students should be able to:
a) solve simple kinematic and optical problems involving the use of the special Lorentz transformation;
b) view space-time from a four-dimensional perspective and appreciate the relativistic principle of causality and its consequences;
c) apply the principles of relativistic mechanics to the kinematics of collisions between elementary particles

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0 Other hours: 11 examples classes. Monitoring of progress: Regular examples sheets.

Outline Syllabus:
Historical Survey. The special Lorentz Transformation and its consequences. The 4D approach to space-time, Lorentz vectors and causality. Relativistic mechanics, with applications to collisions between elementary particles.

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Detailed Syllabus:

1. Historical survey: inertial frames, the Michelson-Morley experiment, special relativity and the consequent relativity of simultaneity and temporal order.
2. Special Lorentz transformation, Fitzgerald contraction, time dilation, twin paradox, transformation of velocities.
3. Relativistic optics: transformation of plane waves, aberration and Doppler formulae.
4. Space as a 4D continuum: Lorentz transformations, Lorentz 4-vectors, time-like, null and space-like vectors, the light cone, causality.
5. Relativistic mechanics: world paths of massive particles and photons, 4-velocity and 4-momentum of a massive particle, 4-momentum of a photon via quantum mechanics, conservation of 4-momentum in collisions between elementary particles, centre of momentum and laboratory frames of reference, applications; the relativistic version of Newton's second law of motion, 4-force and 4-acceleration.

Booklist:

1. W.Rindler, Introduction to Special Relativity, Clarendon Press, 2nd edition, 1991
2. R. Resnick and D. Halliday, Basic Concepts in Relativity, McMillan Publishing Company, 2nd edition, 1991.

Informal Description:
To explain observed features of the propagation of light, our classical view of space and time has to be replaced by the special theory of relativity. This theory has some surprising consequences - which of a pair of events happened first may depend on the speed of the observer, moving clocks run slow, an accelerating particle gets heavier as its speed increases, and mass can be converted into energy via the famous formula $E = mc^2$. Special relativity is essential to the understanding of general relativity (gravitation, black holes, etc.) not covered in this module.

Assessment:
85% 2-hour written examination at end of semester, 15% coursework.

MATH2420 Multiple Integrals and Vector Calculus
Semester: 1 Credits: 10 Level: 2
Prerequisites: MATH 1400. ***Exclusion: not with MATH 2360.***
Key Topics Assumed: Differentiation; integration; equation for straight line in vector form; equation of a circle; trigonometric functions; dot and cross products of vectors; determinants.
Programmes of Study: Mathematical Studies; Joint Honours (Science).

Aims: To develop methods for evaluating multiple integrals; to discuss the basic tools of vector calculus and the theorems of Gauss and Stokes.

Objectives: On completion of this module, students should be able to:

a) evaluate line, surface and volume integrals using Cartesian and polar coordinates;
b) change variables in double integrals using Jacobians;
c) calculate the gradient of a scalar field and the divergence and curl of a vector field, together with associated quantities such as the Laplacian;
d) use the divergence theorem and Stokes' theorem in the manipulation of multiple integrals.

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MATH 2420 Multiple Integrals and Vector Calculus *continued*

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Vector calculus: gradient, divergence and curl. Line, surface and volume integrals. The divergence theorem and Stokes' Theorem.

Detailed Syllabus:
1. Coordinate systems.
2. Scalar and vector fields.
3. Gradient and directional directive: Divergence and curl.
4. Expansion formulas: Second order differential functions, the Laplacian.
5. Line integrals
6. Surface integrals: change of limits in repeated integrals, transformation of coordinates and Jacobians, normal to a general surface and evaluation of surface integrals by projection.
7. Volume integrals.
8. Flux and the divergence theorem.
9. Circulation and Stokes' Theorem.

Booklist:
1. M. R. Spiegel, Theory and Problems of Vector Analysis, McGraw-Hill, 1974*.
2. E. Kreyszig, Advanced Engineering Mathematics, Wiley, 7th edition, 1993.
3. P.V. O'Neil, Advanced Engineering Mathematics, PWS-Kent Publishing, 4th edition, 1995.
4. A.C. Bajpai, L.R.Mustoe, D.Walker, Advanced Engineering Mathematics, Wiley, 1990.
5. C.R. Wylie and L.C. Barrett, Advanced Engineering Mathematics, McGraw-Hill, 5th edition, 1982.
6. P.C.Matthews, Vector Calculus, 1998.

Informal Description: Vector calculus, an extension of ordinary differential and integral calculus, is the normal language used in applied mathematics for solving problems in two and three dimensions. This module starts with a discussion of scalar and vector functions in 3 dimensions, the ways they can represent physical objects (curves, surfaces) and their differential properties (gradient, divergence and curl). It continues by extending the familiar idea of integration in one dimension along the (straight) *x*-axis to integration along a curve and then considers integration over surfaces (2 dimensions), and through volumes (3 dimensions). Finally these are drawn together with the divergence and curl studied at the start of this module in the famous integral theorems of Gauss and Stokes. These theorems show the close connections which exist between line, surface and volume integrals. A knowledge of vector calculus is essential for further study in many areas of applied mathematics.

Assessment: 85% 2 hour written examination at end of semester, 15% coursework.

MATH2431 Fourier Series, Partial Differential Equations, and Transforms
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH2360 or MATH2420, or equivalent.
Exclusion: not with MATH2370.
Key Topics Assumed: Basic Calculus in one and several variables. ODEs.
Programmes of Study: Mathematical Studies; Joint Honours (Science).

Aims: To discuss Fourier series and Fourier and Laplace transforms and their application to the solution of classical Partial Differential Equations of mathematical physics

Objectives: On completion of this module, students should be able to:
a) obtain the whole or half range Fourier series of a simple function;
b) apply the method of separation of variables to the solution of boundary and initial value problems for the classical PDEs of mathematical physics in terms of Cartesian coordinates.
c) obtain the Fourier transforms of simple functions and apply Fourier transforms to the solution of classical PDEs.
d) obtain the Laplace transforms of simple functions and apply Laplace transforms to the solution of initial value problems for linear ODEs with constant coefficients.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practical: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Fourier series, separation of variables for the classical PDEs of mathematical physics, Fourier and Laplace transforms.

Detailed Syllabus:
1. Fourier series (whole and half range) with examples.
2. Solution of boundary and initial value problems for the heat equation, Laplace's equation and the wave equation (in terms of Cartesian coordinates) by separation of variables.
3. Fourier and Laplace transforms, definitions and basic properties (including the convolution theorem), simple examples, applications to the solution of linear PDEs and ODEs.

Booklist:
1. M. A. Pinsky, Introduction to Partial Differential Equations with Applications, McGraw-Hill, 2nd edition, 1991.
2. W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, Wiley, 6th Edition 1996.

Informal Description: Many real world situations can be modelled by one of three partial differential equations:
1. Laplace's equation, which describes e.g. the steady flow of heat or electric charge in a metal or the behaviour of the gravitational potential in the solar system.
2. The heat (or diffusion equation), which describes e.g. the unsteady flow of heat in a metal or the dispersal of cigarette smoke through a room.
3. The wave equation, which describes e.g. waves on the surface of the sea or vibrations of a plucked guitar string.

This module discusses these equations and methods for their solution. In particular, use is made of the remarkable result of Fourier that almost any periodic function (i.e. one whose graph endlessly repeats the same pattern) can be represented as a sum of sines and cosines, called its *Fourier series.* An analogous representation for non-periodic functions is provided by the *Fourier transform* and the closely related *Laplace transform.*

Assessment: 85% 2-hour written examination at end of semester, 15% coursework.

MATH2450 Mathematics for Geophysical Sciences 3
Semester: 1 Credits: 10 Level: 2
Prerequisites: MATH1150 and MATH1460, or equivalent.
Exclusions: not with MATH1060, MATH2360, MATH2420
Programmes of Study: Geophysical Sciences.

Aims: To provide the students with sufficient Mathematical background for understanding their studies in Geophysical Sciences.

Objectives: On completion of this module, students should be able to:
a) carry out basic manipulations involving determinants and matrices;
b) find eigenvalues and eigenvectors of given matrices;
c) calculate the gradient of a scalar field and the divergence and curl of a vector field;
d) evaluate line, surface and volume integrals using Cartesian and polar coordinates.

Methods of teaching:
Hours: Lectures: 22 Tutorials: Practicals: 0 Other Hours: 11 examples classes
Monitoring of progress: Regular example sheets.

Outline Syllabus:
Determinants: Matrices, eigenvalues and eigenvectors. Gradient, divergence and curl. Laplacian. Line, surface and volume integrals.

Detailed Syllabus:
Determinants and Matrices: Determinants and solution of linear equations. Basic matrix algebra. Transpose and inverse of a matrix. Symmetric, orthogonal and Hermitian matrices. Eigenvalues and eigenvectors. Diagonalisation of real symmetric matrices; quadratic forms.
Vector Calculus: Gradient, divergence and curl. Second order derivatives; the Laplacian; vector identities. Expressions in spherical polar coordinates. Line, surface and volume integrals involving vector fields. Flux and the divergence theorem; Circulation and Stokes' theorem.

Booklist:
1. G. Stephenson, *Mathematical Methods for Science Students*, Longman, 2nd edition, 1973.
2. P. V. O'Neil, *Advanced Engineering Mathematics,* PWS Publishing, 4th edition, 1995.
3. K. A. Stroud, *Further Engineering Mathematics* : Programmes and problems, Macmillan, 3rd edition, 1996.
4. M. L. Boas, *Mathematical Methods in the Physical Sciences*, Wiley, 2nd edition, 1983.
5. F. B. Hildebrand, *Advanced Calculus for Applications,* Prentice Hall, 2nd edition, 1976.

Informal Description: The topics covered in this module are essential mathematical tools for treating many physical phenomena. Matrices provide a powerful tool for storing, displaying and manipulating information about linear systems of algebraic and differential equations. They are, for example, used extensively in the analysis of vibrating systems such as those encountered in seismology.
The operations of differentiating and integrating scalar and vector fields arise naturally in areas of geophysics such as fluid flow and heat transfer.

Assessment: 85% 2 hour written examination at end of semester, 15% Coursework.

MATH2490 Mathematics for Geophysical Sciences 4
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH 2450, or equivalent.
Programmes of Study: Geophysical Sciences.

Aims: To provide students with sufficient Mathematical background for understanding their studies in Geophysical Sciences.

Objectives: On completion of this module, students should be able to:
a) solve ordinary differential equations using series solutions, obtain properties of these solutions and relationships between them;
b) use separation of variables combined with either Fourier series or Fourier transforms to solve the Laplace, diffusion and wave equation in Cartesian, spherical and cylindrical polar coordinates;
c) obtain the Fourier transforms of simple functions; solve simple ordinary differential equations using Fourier transforms.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Ordinary differential equations, series solutions, properties. Solution of partial differential equations, separation of variables. Fourier transforms.

Detailed Syllabus:
Ordinary Differential Equations
Introduction to Sturm-Liouville theory - eigenvalues, eigenfunctions, differential operators, orthogonality. Series solutions of ODEs - Frobenius' method. Legendre's equations and Legendre polynomials. Bessel's equations. Generating functions and recurrence relations.
Partial Differential Equations
Laplace's equation, diffusion equation, wave equation. Point source solution and Green's function. Separation of variables in cylindrical and spherical coordinates.
Fourier Transforms
Fourier sine and cosine transforms and their relationship to Fourier series. Relationship to discrete Fourier transforms. Complex Fourier transforms. Inverse transform and transform pair. Applications to the solution of differential equations. The uncertainty principle. Properties - transforms of derivatives, convolution theorem, transfer functions.

Booklist:
1. P.V. O'Neil, *Advanced Engineering Mathematics,* Wadsworth, 1983.
2. G.B. Arfken & H.J. Weber, *Mathematical Methods for Physicists*, Academic Press, 1995.
3. E. Kreyszig, *Advanced Engineering Mathematics*, Wiley, 1999.

Informal Description:
This module introduces students to the mathematical techniques required to solve differential equations arising in the Geophysical sciences.

Assessment: 85% 2 hour written examination at end of semester, 15% Coursework.

MATH2600 Numerical Analysis
Semester: 1 Credits: 10 Level: 2
Prerequisites: (MATH 1932 or MATH1960) and (MATH 1015 or MATH1331), or equivalent.
Key Topics Assumed: Basic Calculus. Basic Linear Algebra.
Programmes of Study: Mathematics; Mathematics with Finance; Theoretical Physics.

Aims: To show how to tackle by numerical methods many fundamental mathematical problems that cannot be solved by analytical means.

Objectives: On completion of this module, students should be able to:
a) describe how errors arise in computations;
b) solve simple non-linear equations by root-finding techniques;
c) calculate the interpolating polynomial through discrete data points;
d) derive and use quadrature formulas;
e) write down suitable numerical schemes for solving first order ordinary differential equations;
f) solve linear systems of algebraic equations using Gaussian elimination and *LU* factorisation.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Computer arithmetic; errors. Nonlinear equations in one variable. Polynomial interpolation; splines. Numerical integration. Numerical solution of ordinary differential equations. Solution of systems of linear equations using matrix methods.

Detailed Syllabus:
1. *Introduction*. Computer arithmetic. Errors; round-off error, truncation error.
2. *Solution of nonlinear equations in one variable*. Bisection method; fixed point iteration; Newton-Raphson iteration; secant method. Order of convergence.
3. *Interpolation.* Lagrange interpolation; error term. cubic splines.
4. *Numerical integration*. Trapezoidal rule. Method of undetermined coefficients. Simpson's rule. Newton-Cotes formulae. Composite integration methods. Richardson extrapolation; Romberg integration.
5. *Ordinary differential equations* (*initial value problems*)
   Euler's method; errors. Runge-Kutta methods. Multi-step methods. Stability.
6. *Linear systems of algebraic equations*. Gaussian elimination. Pivoting. *LU* factorisation.

Booklist:
1 R.L.Burden and J. D. Faires, Numerical Analysis (8th edition), Thompson.*
2. G.F. Gerald and P.O. Wheatley, Applied Numerical Analysis (7th edition) Addison-Wesley, 2004.*
3. G.M.Phillips and P.J. Taylor, Theory and Applications of Numerical Analysis Academic Press, 1973.
4. A. Ralston and P Rabinowitz, A First Course in Numerical Analysis, Dover, 2001.
5. S.D.Conte and C.deBoor, Elementary Numerical Analysis, McGraw-Hill.

Informal Description: Most of the problems that students meet when they are introduced to, for example, integration or differential equations, will have nice analytic solutions. In real life though this is typically not the case and so solutions have to be evaluated numerically (i.e. with the aid of a computer). This module explains how to express mathematical operations in terms of operations that can be performed on a computer. It is a good preparation for the Level 3 module in Numerical Methods (MATH 3473)

Assessment: 85% 2-hour written examination at end of semester; 15% coursework.

MATH2610 Oscillations and Waves

Semester: 1 Credits: 10 Level: 2
Prerequisites: Calculus (MATH 1932 or MATH1960 + MATH1970) and Linear Algebra (MATH1015 or MATH1331); Mechanics (MATH1382), or equivalents.
Corequisites: MATH 2200, MATH 2360, or equivalent.
Key topics assumed: Differentiation, integration, second order differential equations with constant coefficients, dot product, matrix determinant, Newton's 2nd Law of Motion, kinetic and potential energy.
Programmes of Study: BSc/MMath; Theoretical Physics.

Aims: This module provides an introduction to the theory of small-amplitude linear oscillations of systems of finitely many particles and of continuous systems (strings, membranes). An introduction to Lagrange's mechanics; methods of solutions for the corresponding differential equations (normal modes, D'Alembert's solution, separation of variables and the Fourier method).

Objectives: On completion of this module, students should be able to:
a) formulate and solve equations for simple harmonic motion with damping and external force;
b) formulate and solve dynamical problems for systems of particles and continuous systems in terms of the Hamilton principle and Euler's equations;
c) find normal modes and eigen-frequencies for complex systems;
d) solve problems associated with the 1-dimensional wave equation;
e) apply the technique of separation of variables to solve initial boundary value problems for the wave equation in one, two and three dimensions;
f) use the Fourier method to solve wave problems.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Simple harmonic motion; Hamilton's principle and Euler's equations; Normal modes of oscillation; separation of variables; Fourier solution of the wave equation; D'Alembert solution of the wave equation.

Detailed Syllabus:
1. Revision of simple harmonic motion and damped harmonic motion with external forcing.
2. Introduction to the Calculus of Variations.
3. The Hamilton principle, Lagrangian, Euler equations.
4. Normal modes and eigen-frequencies.
5. Derivation of the wave equation for a stretched string.
6. D'Alembert's solution for an infinite string.
7. Initial boundary problem for the wave equation;
8. Separation of variables for the wave equation, eigen-frequencies.
9. Initial boundary value problem for membranes.

Booklist:
1. H. Goldstein, Classical Mechanics, 3rd edition, Addison-Wesley, 2000.
2. L.D. Landau and E.M. Lifshitz, Mechanics, vol. 1 of "Course of Theoretical Physics", 3rd edition, Pergamon Press, 1982.
3. J.L. Synge and B.A. Griffith, Principles of Mechanics, 3rd edition, McGraw-Hill, 1959.

Informal Description: This module provides an introduction to the theory of small-amplitude (linear) oscillations of systems of finitely many particles or of a continuous system such as strings or membranes (a paradigm for the theory of sound, water or electromagnetic waves). Normal modes and eigen-frequencies are introduced, as are the Hamilton Principle, Lagrangian and Euler's equations, which lead on in subsequent modules to Hamiltonian Dynamics and Quantum Mechanics and Rigid Body Mechanics.

Assessment: 85% 2 hour written examination at end of semester; 15% coursework.

MATH2620 Fluid Dynamics
Semester: 2 Credits: 10 Level: 2
Prerequisites: (MATH 1382 and MATH 2360) or (MATH 1150 and MATH1460), or equivalent. ***Exclusion:- not with MATH 3501***
Programmes of Study: Mathematics; Theoretical Physics; Geophysical Sciences.

Aims: To demonstrate how a wide range of important physical phenomena can be understood using relatively simple mathematics, coupled with a sound insight into basic physics.

Objectives: On completion of this module, students should be able to:
a) calculate the position of the streamlines, particle paths and streak lines for simple velocity fields.
b) derive Bernoulli's equation for steady flow and for irrotational flow;
c) derive the governing equations for simple one-dimensional flows;
d) calculate simple irrotational flows, such as flow past a sphere.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Practicals: 0
Other Hours: 11 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus: Velocity field; kinematics; acceleration; conservation of mass; stream function; pressure; Euler's equations; momentum equation; flows in channels; vorticity; potential flow in 3 and 2 dimensions.

Detailed Syllabus:
1. Specification of the velocity field. Kinematics; acceleration; conservation of mass; stream function.
2. Euler's equations for an incompressible, inviscid fluid.
3. Pressure in an inviscid fluid. Bernoulli's equation. Momentum equation in integral form.
4. Simple, quasi - unidirectional flows in channels (waves, bores, etc.)
5. Vorticity and conditions for irrotationality.
6. Velocity potential; simple examples in 3-D.
7. 2-D potential flow with examples; lift on a wing.

Booklist:

1. A. R. Paterson, A first course in fluid dynamics, Cambridge UP, 1983.
2. D. J. Acheson, Elementary fluid dynamics, Oxford UP, 1990.

Informal Description: Fluid dynamics is the science of motion of anything that flows, liquid or gas. Flowing fluids are of central importance in an enormous range of applications in science and engineering, from astrophysics to physiology, chemical engineering to meteorology, lubrication to combustion, water waves to acoustics, etc.
The principle examples analysed in this course are the hydraulics of rivers and canals and the aerodynamics of aircraft flight. Newton's laws are applicable to every particle of a fluid, which accelerates in response to both long-range forces (e.g. gravity) and short-range forces (pressure) exerted by the other particles around it. It is therefore possible to write down equations governing the velocity and pressure fields in a fluid, and these are solved in a variety of physical situations, giving the student a feel for how fluids behave, and experience in modelling everyday phenomena.

Assessment: 85% 2-hour written examination at end of semester. 15% coursework.

MATH2640 Introduction to Optimisation
Semester: 1 Credits: 10 Level: 2
Prerequisites: MATH1331 and MATH1351 and MATH1932 or equivalent.
Programmes of Study: Mathematics with Finance

Aims: To provide a collection of theoretical techniques for determining optimal extrema of functions of several variables, either with or without constraints, and to apply these in the context of maximising profit and/or revenue in financial scenarios.

Objectives: By the end of this module, students should be able to:
a) determine the definiteness of both unconstrained and constrained quadratic forms;
b) determine exactly the extrema of functions of several variables, either with or without constraints, using a variety of techniques, namely: Lagrange multipliers, Bordered Hessians and Kuhn-Tucker theory;
c) apply the theory in b) to profit- and/or revenue-maximisation problems in economics.

Methods of teaching: Hours: Lectures 20 Tutorials 10 Revision 3 (in week 11)
Monitoring of progress: Regular example sheets.

Outline syllabus: Several-variable calculus, quadratic forms, unconstrained optimisation, constrained optimisation via Lagrange multipliers, applications in economics.

Detailed syllabus:
Several-variable calculus, (6 lectures): Representing and visualising functions of 2 variables. Partial derivatives, total derivatives and chain rule. Gradient vectors and directional derivatives. Implicit differentiation, change of variables, Jacobian. Several-variable Taylor series, Hessian matrix, stationary points.
Unconstrained optimisation (4 lectures): Quadratic forms and eigenvalues. Definiteness using principal minor tests, stationary points, local extrema, unconstrained optimisation, applications in economics, Cobb-Douglas production functions.
Constrained optimisation (10 lectures): Constrained maximisation with equality constraints, Jacobian derivative, first-order conditions, constraint qualifications, Lagrange multipliers, constrained quadratic forms, bordered Hessian, constrained maximisation with inequality constraints and mixed constraints, constrained minimisation. Kuhn-Tucker theory (with applications in economics), economic interpretation of Lagrange multipliers, second-order conditions, bordered Hessian of Lagrangian.

Booklist:
1. C P Simon L Blume, *Mathematics for Economists,* W W Norton, 1994.* (Highly recommended.)
2. Alpha C Chiang, *Fundamental Methods of Mathematical Economics* (International Edn.), McGraw-Hill, 1984. (Very good.)
3. A Ostazewski, *Mathematics in Economics: Models Methods,* Blackwell, 1993.

Informal description:
Optimisation – the quest for the best – plays a major role in financial and economic theory, e.g. in maximising a company's profits or minimising its production costs. How to achieve such optimality is the concern of this course, which develops the theory and practice of maximising or minimising a function of many variables, either with our without both equality and inequality constraints. This course lays a solid foundation for progression onto more advanced topics, such as dynamic optimisation, which are central to the understanding of realistic economic and financial scenarios.

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It should be observed from the above syllabus that neither gradient methods nor search methods are covered in this course, such methods being more suited to a course in programming. Here, only purely mathematical techniques are used, with a definite emphasis on applications in Mathematical Finance.

Assessment: 90% 2-hour written examination; 10% coursework, based on four assessed example sheets.

MATH2715 Statistical Methods
Semester: 1 Credits: 10 Level 2
Prerequisites: MATH 1725 and either MATH1932 or MATH 1960 or MATH 1050 or equivalents.
Key topics assumed: Basic definitions of probability, expectation and variance. Definitions of binomial, Poisson, exponential, normal, geometric distributions. Probability generating functions. Differentiation. Integration.
Programmes of Study: Mathematics; Mathematical Studies; Mathematics with Finance: Joint Honours.

Aims: To introduce mathematical techniques for analyzing probability distributions and to develop the tools for statistical model building.

Objectives: On completion of this module, students should be able to
a) manipulate univariate and bivariate probability distributions, including moments and transformations;
b) use univariate moment generating functions to derive the classic limit theorems of probability;
c) understand the principles of statistical modelling, from data collection to model assessment and refinement;
d) deal with robustness problems in statistical estimation;
e) carry out elementary Bayesian statistical modelling.

Methods of teaching: Hours: Lectures 22 Tutorials: 0 Practicals: 0
Other hours: 10 examples classes. Monitoring of progress: marked examples sheets.

Outline syllabus: univariate and bivariate distributions; moment generating functions; estimation; testing; statistical modelling; robustness; Bayesian analysis.

Detailed syllabus.
1. Moments and transformations for univariate probability densities.
2. Conditional and marginal distributions for bivariate distributions; bivariate normal distribution.
3. Moment generating functions; law of large numbers; central limit theorem.
4. Issues in statistical modelling: data collection; model formulation; model assessment; model diagnostics; model refinement.
5. Estimation; method of moments; maximum likelihood.
6. Hypothesis testing. Type 1 and Type 2 errors; power; likelihood ratio test.
7. Bayesian modelling; prior and posterior distributions.

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MATH2715 Statistical Methods *continued*

Booklist:
1. J.A. Rice, *Mathematical Statistics and Data Analysis*. Duxbury Press, 2nd edition. 1995.
2. D.D Wackerl, W. Mendenhall and R.I. Scheaffer, *Mathematical Statistics with Applications*. Duxbury Press, 6th edition, 2002.
3. S Ross, *A First Course in Probability*, Prenctice Hall, 6th edition, 2002.
4. G. Casella and R.L. Berger, *Statistical Inference*, 2nd edition, Duxbury Press, 2002.

Informal Description:
Statistical models are important in many applications. They contain two main elements: a set of parameters with information of scientific interest (e.g. the mean of a normal distribution, or the slope in a regression model) and an "error distribution" representing random variation. This module lays the foundations for the analysis of such models. The first part deals with suitable choices for the "error" term, in particular looking carefully at methods for analyzing continuous distributions. The second part focuses on the construction of appropriate statistical models and the development of methods to gain information about the unknown parameters. The main emphasis is on the use of likelihood methods. We shall use practical examples from a variety of statistical applications to illustrate the ideas.

Assessment: 80% 2-hour written examination at the end of the semester; 20% coursework.

This module is a prerequisite for the majority of further Statistics modules.

MATH 2730 Analysis of Experimental Data

Semester: 1 Credits: 10 Level: 2
Prerequisite: MATH1725 or equivalent.
Corequisites: MATH2715, or equivalent.
Key Topics Assumed: Simple matrix Algebra. t Distribution. Confidence intervals. Simple linear regression – MATH1725.
Programmes of Study: Mathematics; Mathematical Studies; Mathematics with Finance; Joint Honours.

Aims: To investigate the general linear model via the analysis of variance technique.

Objectives: On completion of this module, students should be able to:
a) recognize and apply various analysis of variance models;
b) interpret results of analysis of variance methods.

Methods of teaching: Hours: Lectures: 22 Tutorials: 0 Examples classes: 9.
Monitoring of progress: Regular example sheets.

Outline Syllabus: Introduction to analysis of variance; randomized block designs; two-way analysis of variance; nested designs; simple linear regression; analysis of these designs using a statistical computing package (e.g. R).

Detailed Syllabus:
1. Introduction to analysis of variance : one-way layout model, model adequacy; testing sub-hypotheses; random effects, components of variance.
2. Randomized complete block design.
3. Two-way analysis of variance : interaction; fixed and random effects, mixed models.
4. Nested designs.
5. Simple linear regression : properties of estimators; matrix representation; residual analysis.

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MATH 2730 Analysis of Experimental Data *continued*

Booklist:
1. D. C. Montgomery, *Design and Analysis of Experiments*, 5th edition, Wiley, 2001 (or earlier editions).
2. A.Dean and D.Voss, *Design and Analysis of Experiments*, Springer, 1999.

Informal Description: Experimental design investigates the general linear model via the analysis of variance technique with its wide variety of designs and also through simple linear regression. In analysis of variance, the one-way layout and two-way layout are considered with reference to fixed or random effects and interaction. The nested design is also considered. Model adequacy is examined through the analysis of residuals and assessment of fit. In simple linear regression, the distributions of model parameters are derived leading to hypothesis testing and confidence intervals for the regression line. Residuals are examined for adequacy of fit and where appropriate the lack of it is assessed. Throughout this course, many practical examples are solved and illustrated with the R statistical computing package.

Assessment: 80% 2-hour written examination, 20% coursework.

MATH2740 Environmental Statistics
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH2715, or equivalent.
Key Topics Assumed: Binomial, Poisson and Normal distributions, probability generating functions, hypothesis testing, chi-square goodness-of-fit test.
Programmes of Study: Mathematics; Mathematical Studies; Joint Honours.

Aims: To introduce statistical concepts and models for analysing data of an environmental nature.

Objectives: On completion of this module, students should be able to:
a) analyse data of a spatial nature;
b) analyse models when applied to the analysis of categorical data arising from observational studies.

Methods of teaching: Hours: Lectures: 22 Classes: 5 Practicals: 5
Other Hours: 4 examples classes. Monitoring of progress: Regular example sheets and practicals.

Outline Syllabus: Spatial point patterns, spatial autocorrelation, categorical data analysis, log-linear models.

Detailed Syllabus:
1. Types of data
2. Spatial point patterns: contagious distributions.
3. Quadrat analysis: testing for non-randomness.
4. Distance methods: nearest neighbour analysis.
5. Spatial autocorrelation: join count statistics; testing hypotheses of spatial correlation.
6. Categorical data analysis: log-linear models; goodness of fit; three-dimensional tables; model selection.

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Booklist:

1. G. J. G. Upton and B. Fingleton, *Spatial Data Analysis by Example,* Vols 1 & 2, Wiley, 1985 and 1989.*
2. S. E. Fienberg, *The Analysis of Cross-Classified Categorical Data,* 2nd edition, MIT Press, c1980.

Informal Description: This course will make use of examples based on environmental data; some of the topics being 'driven' by examples. Environmental data may result from observational studies, or may be of a spatial nature with observations collected at particular locations. For example, incidences of leukaemia may be claimed to be the result of nuclear power stations. The analysis of such data will use methods in spatial statistics.

Assessment: 80% 2 hour written examination, 20% coursework.

MATH2750 Introduction to Markov Processes
Semester: 2 Credits: 10 Level: 2
Prerequisites: MATH1715, or equivalent.
Key Topics Assumed: Poisson distribution. Conditional probability. Solving first-order differential equations/difference equations.
Programmes of Study: Mathematics; Mathematical Studies; Mathematics with Finance; Joint Honours.

Aims: To provide a simple introduction to stochastic processes.

Objectives: On completion of this module, students should be able to:
a) have an understanding of, and ability to solve, elementary problems of first passage times;
b) understand about barriers in a random walk;
c) solve equilibrium distribution problems;
d) have a knowledge of Markov chains and elementary theory thereof;
e) learn about continuous time Markov process models;
f) have knowledge about the Poisson process;
g) understand the use of simulation in modelling.

Methods of teaching: Hours: Lectures 22 Tutorials: 0 Practicals: 2
Other Hours: 10 examples classes. Monitoring of progress: Regular example sheets.

Outline Syllabus:
Random walks, transition probabilities, first passage times, barriers; Markov chains, classification of states, irreducibility, equilibrium and stationary distributions; Poisson process and other continuous-time Markov processes.

Detailed Syllabus:

1. Random walks: transition probabilities, first passage time, recurrence, absorbing and reflecting barriers, gambler's ruin problem.
2. Branching chain, probability of ultimate extinction.
3. General theory of Markov chains: transition matrix, Chapman-Kolmogorov equations, classification of states, irreducible Markov chains, stationary distribution, convergence to equilibrium.

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4. Poisson process and its properties. Birth-and-death processes, queues.
5. Markov processes in continuous time with discrete state space: transition rates, forward and backward equations, stationary distribution.
6. Simulation of stochastic processes.

Booklist:

1. D.R. Cox and H.D. Miller, *The Theory of Stochastic Processes*, Chapman & Hall, 1977.
2. G.R. Grimmett and D.R. Stirzaker, *Probability and Random Processes*, 2nd edition, Clarendon Press, 1992.
3. P.G. Hoel, S.C. Port and C.J. Stone, *Introduction to Stochastic Processes*, Houghton Mifflin, 1972.
4. D.L. Isaacson and R.W. Madsen, *Markov Chains: Theory and Applications*, Wiley, 1976.
5. H.C. Tuckwell, *Elementary Applications of Probability Theory*, Chapman & Hall, 1988.

Informal Description:

A stochastic process refers to any quantity which changes randomly in time. The number of people in a queue, the capacity of a reservoir, the size of a population, are all examples from the real world. The linking model for all these examples is the simple random walk. The gambler's ruin problem is an example of a simple random walk with two absorbing barriers. Replacing these absorbing barriers with reflecting barriers provides a model for reservoir capacity. With appropriate modifications the random walk can be extended to model stochastic processes which change over continuous time, not just at regularly spaced time points. As a birth-death process this can be used to model population growth, the spread of diseases like AIDS, traffic flow, the queuing of students at a coffee bar, and so on.

Assessment:

90% 2 hour written examination, 10% practicals.

MATH2770 Medical Statistics
Semester: 2 Credits: 10 Level:2
Prerequisites: MATH1725, or equivalent.
Key Topics Assumed: Hypothesis testing, normal distributions, t distribution, summarising data.
Programmes of Study: Mathematics; Mathematical Studies; Mathematics with Finance; Joint Honours.

Aims: To provide an introduction to statistical methods of specific interest in medical applications.

Objectives: On completion of this module, students should be able to:
a) understand different sampling methods;
b) describe various types of clinical trials;
c) carry out parametric and nonparametric tests;
d) analyse survival data.

Methods of teaching: Hours: Lectures 22; Examples classes 7.
Monitoring of progress: Regular example sheets.

Outline Syllabus: Design of clinical trials; nonparametric techniques; epidemiology; survival analysis.

Detailed Syllabus:
1. *Design of medical studies*. Double-blind randomized clinical trials; cross-over designs; cross-sectional, cohort and case-control studies; bias, confounding; observational studies.
2. *Nonparametric tests.* Mann-Whitney; Wilcoxon; Kolmogorov-Smirnov.
3. *Epidemiology*. Rates of disease; incidence and prevalence; risk and odds.
4. *Survival analysis.* Parametric models; Kaplan-Meier estimator.

Booklist:
1. Martin Bland, *An Introduction to Medical Statistics*, Oxford Medical Publications, 1997.
2. D.G. Altman, *Practical Statistics for Medical Research*, Chapman and Hall, 1991.
3. L.D. Fisher and G. van Belle, *Biostatistics; a Methodology for the Health Sciences*, Wiley, 1993.

Informal Description: New drugs and other treatments frequently appear on the market. However, before this stage, much research is carried out on a drug's effectiveness; this may often be measured in relation to other existing treatments. Issues involved include how to collect reliable data which is truly representative - without treating humans as guinea pigs. In medical trials (for example, heart transplant students) the success of the outcome may only be measurable some time later, so an analysis of the survival times can be carried out.

Assessment: 80% 2 hour written examination, 20% coursework.

MATH2800 Mathematics into Schools
Semesters 1 and 2 10 credits Level 2
Programmes of study: Mathematics, Mathematical Studies, Joint Honours.
Note: This module is normally restricted to Year 2 students. Students in Years 3 or 4 wishing to take it must seek permission.
Corequisite: Students taking this module must be taking at least another 40 credits in Mathematics.

The number of students able to enrol on this module will be limited. Enrolment will depend on a school or college placement being available.

Students wishing to take this module must inform Dr Slomson (a.slomson@leeds.ac.uk**) no later than Wednesday May 10th**. There is a briefing meeting on Tuesday, May 2nd at 1pm in Roger Stevens Lecture Theatre 12, to help explain what this module involves.

Aims
1. To allow students to work in collaboration with a secondary school or 6th form college on a project relevant to the need of the school or college in Mathematics.
2. To allow students to design, negotiate and manage their work in co-operation with an academic supervisor and a member of staff from the school or college.
3. To encourage school pupils to participate actively in a Mathematics based project in collaboration with university students.
4. To raise the profile of Mathematics as an exciting, challenging and rewarding discipline to study at university.

Teaching methods
1. Induction Workshop to be given by *Campus Connect:* 7 hours.
2. Workshop on the preparation of and use of teaching materials, and Mathematics activities for schools: 3 hours.
3. Meetings with school or college mentor: 4 hours.
4: Meetings with module tutor: 4 hours

Description
1. Students taking this module will be placed in a local school or college via Campus Connect with a remit to help organise Mathematics activities within the school or college, through Mathematics lessons or an existing Mathematics club, or by helping teachers to set up a Mathematics club.
2. Students will, during their time with the school or college pupils, organise a Mathematics based project (or projects) with the aim of promoting the excitement of Mathematics.
Such a project or projects may be at any secondary school level appropriate to the needs of the school or college.
3. Students will compile a *Learning Log* recording and reflecting on their activities within the school or college.

Assessment
1. School staff assessment of how successful the student has been in achieving the aims that were agreed at the outset, and of the students general; development (20%)
2. A summary of the Learning Log. (20%)
3. Oral presentation setting out the aims, approach, methods, results and conclusions of the project. (20%).
4. A written report of 1500-3000 words to which would be attached copies of all the teaching/project materials. (40%)

EDUC2071 School Mathematics from an Advanced, Undergraduate Perspective
Semester: 2; Credits 10; Level: 2.
Programmes of study: BSc and MMath Mathematics, Mathematical Studies, Joint Honours.

Notes: The number of students able to enrol for this module may have to be limited.

Aims: (1) To study aspects of the school mathematics curriculum from an undergraduate perspective; (2) To discover connections within and between different branches of mathematics which may not have been apparent when the topics were learned at school; (3) To increase awareness of educational issues concerning the mathematics curriculum; (4) To relate the issues of the course to personal experiences of the school curriculum.

Objectives. On completion of this module, students should be able to:
a) articulate an awareness of the historical development of ideas in number and algebra, geometry and calculus;
b) describe key curriculum and cultural issues in learning and teaching mathematics, including difficult conceptual problems;
c) demonstrate an appreciation of the role notation plays in developing meaning, and the difficulties which can occur for learners as a result of notational confusion;
d) evaluate ideas and issues presented in relation to both informed opinion and personal involvement with the mathematics curriculum.

Methods of teaching: There will be 22 contact hours (11 two hour sessions), mainly lectures, but including group activities, tutorials and practical tasks as appropriate.

Outline syllabus: The construction and nature of the school mathematics curriculum underlies this course. Particular areas of mathematics such as number and algebra, geometry and calculus will be considered from logical, historical, cultural and educational perspectives in order to appreciate (a) how they contribute to the overall development of mathematical understanding and (b) the complexities of apparently simple concepts and interconnections. Each area considered will include attention to selected key themes and paradigm problems.

Booklist
There is no essential pre-course reading and there is no single book that covers all the themes explored in the course. However, the following books may prove helpful:

1. P.J. Davis and R.Hersh, *The Mathematical Experience,* Penguin Books, 1983.
2. A.G.Howson, *A History of Mathematics Education in England,* Cambridge University Press, 1982.
3. G.G.Joseph, *The Crest of the Peacock: Non-European Roots of Mathematics,* Penguin Books, 1991.
4. T.Nunes and P.Bryant, *Children Doing Mathematics,* Blackwell, 1996.

Informal description: This module is for students who are studying some mathematics in their degree course, and allows participants to revisit, research and enjoy mathematics first encountered at school, and thereby to develop a deeper understanding of aspects of school mathematics, the structure of the curriculum with its aims and objectives, and the difficulties which particular problem areas present for students. The intentions also include encouraging a cultural sensitivity to and educational awareness of the development of mathematical ideas throughout history.

Assessment is 100% coursework and consists of two assignments. The first assignment, equivalent to 1000 words and worth 33%, is halfway through the course. This assignment may be based on particular mathematical problems. The second assignment will be in essay format, about 2000 words long and worth 67%, and is at the end of the semester.

Timetables

Semester 1

	9am	*10am*	*11am*	*12noon*	*1pm*	*2pm*	*3pm*	*4pm*	*5pm*
Monday									
Tuesday									
Wednesday									
Thursday									
Friday									

Semester 2

	9am	*10am*	*11am*	*12noon*	*1pm*	*2pm*	*3pm*	*4pm*	*5pm*
Monday									
Tuesday									
Wednesday									
Thursday									
Friday									

Use of Calculators in Examinations

For some Mathematics modules calculators are not allowed at all. Where they are allowed ***only approved basic scientific calculators may be used in examinations for Mathematics modules.*** (These are the modules with a MATH code; they include some modules which cover Statistics.)

The following models are automatically approved:

- The *Casio fx-82*, *fx*-83, *fx*-85, *fx*-300, *fx*-350 series.
- The *Sharp EL-531* series.

Any calculator meeting our conditions may be used in examinations, provided that you come and show your calculator to us *before* the examinations begin. If it meets our requirements, an “approved” sticker will be put on it. To get approval, bring your calculator to my office (Room 8.18i in the School of Mathematics).

A guide to which calculators are NOT APPROVED
If the answer to *ANY* of the following questions is "**yes**" the calculator is ***not approved**:*

Is it a graphics calculator?
Is it programmable?
Can it store information?
Can it do matrix calculations?
Can it solve calculus problems
Can it solve simultaneous linear equations?
Can it solve quadratic equations?

The following Casio models can all do at least some of these things and so are **not allowed**: the Casio *fx*-115, *fx*-570 and *fx*-991 series (a few early models in these series such as the fx-115S, *fx*-570S and the *fx*-991S may be exceptions to this, but you need to come and check.)

Check it out now! ✓

Dr Alan Slomson
Director of Undergraduate Studies