University of Melbourne

Department of Mathematics and Statistics

Honours Guide 2005

Contents Page

BSc (Hons) Faculty of Science Application Form online:
http://www.ms.unimelb.edu.au/studentinfo/honours/forms.html

NOTE

This Guide has been prepared to assist you in deciding whether to apply to enter honours, and to design your course.

You are advised that the rules governing the Honours program are definitively stated in the official University Handbook. In the event of a disagreement between this guide and the Handbook, it is the Handbook that is to prevail.

Information correct at time of printing. October 2004.

Why Do An Honours Year?

Honours is an extremely valuable year of study. The Honours program in Mathematics and Statistics is designed to train graduates in advanced mathematics and statistics topics, and to provide an opportunity for students to participate in research. The Honours program in Applied Statistics is designed to train graduates in applications of statistical methods, with supporting studies in theoretical statistics and stochastic processes.

The year involves the completion of an Advanced Coursework subject and a Research Project subject.

The following Honours programs are offered in the Department of Mathematics and Statistics:

- a BSc (Hons) in Mathematics and Statistics;
- a BSc (Hons) in Applied Statistics;
- a combined BSc (Hons) in Mathematics and Statistics/Computer Science;
- a combined BSC (Hons) in Mathematics and Statistics/Physics.

Fourth Year Coordinators

The Department of Mathematics and Statistics fourth year coordinators for 2005 are:

Associate Professor Jerry Koliha phone: (03) 8344 9709
email: j.koliha@ms.unimelb.edu.au

Dr Ken Sharpe phone: (03) 8344 6410
email: k.sharpe@ms.unimelb.edu.au

Opportunities After Honours

Study
The skills and qualifications obtained as an Honours graduate can lead on to a higher degree such as a Master of Science or Doctor of Philosophy.

Career
There are many career options for our graduates. Here are some examples of where past graduates have found careers:

actuarial analyst	applied mathematician	business analyst
market researcher	physical chemist	economist
geophysicist	strategic planning manager	applied statistician

An Honours degree is a strong entry point into careers in industry, science and technology.

How is An Honours Year Different From Undergraduate Studies?

Students enrol in an Advanced Coursework subject and a Research Project subject.

Project

The Research Project subject accounts for 25% of the total assessment and involves an independent research project completed under the guidance of an academic who specialises in your area of interest.

A list of the research interests of the Department is outlined in the departmental research report, available from our web page at http://www.ms.unimelb.edu.au. Intending fourth year students should approach individual staff members to discuss possible research projects. Project titles and supervisors should be finalised by 14 January 2005 and recorded on *the form at the back of this booklet*. Performance in the research project will be assessed by a Project Report to be examined by the supervisor and one other departmental member nominated by the fourth year coordinator. The reports are assessed on:

(a) clarity and exposition;

(b) mathematical insight displayed; and

(c) coverage of field, references.

Copies of previous years' research reports can be perused in the Mathematical Sciences Library. Final Submission Date is *5.00pm on Friday 4 November 2005*. Late submission will be penalised. Each student is required to give a seminar on the subject of their Project on Friday 18 November 2005.

Course Work

The Advanced Coursework subject accounts for 75% of the total assessment. All Honours Mathematics and Statistics students must complete 6 subjects of Honours course work. Each subject will be of one Semester length and will consist of 24 lectures (usually 2 per week) some or all of which may be replaced by seminars, guided reading or project work. Full time students usually undertake 4 subjects in the first semester and two subjects in second semester. The subjects will be selected from some of the following areas:

- Algebra
- Analysis
- Applied Statistics
- Discrete Mathematics and Combinatorics
- Geometry and Topology
- Mathematical Physics and Statistical Mechanics
- Methods and Modelling
- Operations Research
- Stochastic Processes

Standard Required

To be awarded an Honours qualification, students enrolled in the BSc (Honours) must achieve an overall weighted average of at least 65% for their Honours studies.

Seminars

Honours students should consider themselves a part of the research strength of the Department and view departmental seminars as a method of broadening their knowledge. It is therefore expected that students will attend all research seminars in the broader area of their chosen field. They are also expected to give two seminars during the Honours year, one on their Project.

Tutoring

Honours students are encouraged to undertake some part-time tutoring in the department. For further information please see Karen Baker (the Director of the First Year Learning Centre) as early as possible to register your interest.

Bachelor of Science (Honours) Entry Requirements

To apply for a place in the Honours program you must satisfy the entry requirements of the Faculty of Science *and* the Department of Mathematics and Statistics.

♥ The *Faculty of Science requirements* for the Bachelor of Science Honours program are as follows:

• Applicants must hold a Bachelor of Science (BSc), Bachelor of Arts and Sciences (BASc) or equivalent qualification recognised by the Faculty of Science.

• Graduates of the University of Melbourne BSc single degree must have a Faculty Honours Score of at least 65%. The Faculty Honours Score is a weighted average based on a student's performance in their best 87.5 points of science study at the 300-level (3rd year). A Faculty Honours Score is not calculated for University of Melbourne BASc or BSc combined course students. For these students the Faculty calculates a weighted average mark for the 300-level science subjects that have been completed. A weighted average of 65% or more is usually required for entry into Honours.

• Applicants who have completed their degree at other institutions must demonstrate that they have achieved an average of 65% or more for the third year science subjects they have studied.

♥ The Department of Mathematics and Statistics requirement is:

• An H3 or better in at least four 300-level Mathematics/Statistics subjects.

Students who do not meet this requirement, but who have achieved very good results in other areas, may be considered for entry to Honours on the recommendation of the Head of the Department of Mathematics and Statistics.

Prospective Honours students should consult the 2005 University Handbook for guidelines to selecting their 300-level Mathematics/Statistics subjects. It is important that they be selected to provide prerequisites for the desired course of Honours study.

General Enrolment Information

Duration and Commencement of the Course

Honours involves one year of full-time study between February and November. A midyear intake is also offered.

Deferment

The Faculty of Science does not allow students who have been offered a place in Honours to defer commencement of the course. Students need to advise the Department of Mathematics and Statistics in writing that they are unable to accept the course offer, and re-apply for a place in the Honours program at a later stage.

Leave of Absence

The Faculty of Science allows students to take leave from the Honours program in exceptional circumstances only. Students wishing to apply for leave from the Honours program must complete a Postgraduate Variation to Enrolment form (available from the Faculty of Science).

HECS

The Faculty of Science offers its Honours degrees on a HECS basis. As from 1 January 1989, the Commonwealth Government introduced the HECS scheme. Apart from those courses which are specified as charging a Course Fee, all courses at the University of Melbourne attract liability under the HECS scheme. The HECS scheme applies to Australian residents. Students can elect to pay their HECS charge 'upfront', that is at the time of enrolment, or they may 'defer' their payment and pay it back through the income tax system. Election to pay up-front attracts a 25% discount. Further information regarding HECS is available from the Faculty of Science.

Melbourne Scholarships

Very few scholarships for the Honours Program are available; for further information contact the Melbourne Scholarships office:
phone: 8344 7467 or 1800 772 244 (free call within Australia)

email: ug-schols@unimelb.edu.au

web: http://www.services.unimelb.edu.au/scholarships/

How Do I Apply

Application forms are available online

http://www.ms.unimelb.edu.au/studentinfo/honours/forms.html

and from the Departmental Office. Forms should be completed and lodged with the Mathematics and Statistics Office by 17 November 2004 for commencement in Semester 1, and by 18 June 2005 for commencement in Semester 2. After these dates talk to the Honours Coordinators.

The Department

Further information on the Department, in particular the research activities of the various groups, can be obtained from our web site:

http://www.ms.unimelb.edu.au

Fourth-year Mathematics and Statistics Honours: prerequisites and recommended subjects at 300 level

Algebra	620-311*, 620-312, 620-321*, 620-322*, 620-351
Analysis	620-311*, 620-312*, 620-321, 620-322
Applied Statistics	620-301, 620-302, 620-371*, 620-372*, 620-374
Discrete Mathematics and Combinatorics	620-301, 620-321, 620-351, 620-352*, 620-353*, 620-381
Geometry and Topology	620-311*, 620-312, 620-321*, 620-322*
Mathematical Physics and Statistical Mechanics	620-331*, 620-332, 620-342, 620-352, 620-353
Methods and Modelling	620-331*, 620-332, 620-342*, 620-381
Operations Research	620-301, 620-302, 620-361*, 620-362
Probability and Stochastic Processes	620-301*, 620-302, 620-311, 620-312, 620-371, 620-372, 620-374

* Prerequisites for specialisation.

Honours Programs Information

BSc (Hons) in Mathematics and Statistics

620-496 BSc (Hons) Mathematics and Statistics Research Project
620-497 BSc (Hons) Mathematics and Statistics Coursework

Coordinators: Associate Professor Jerry Koliha, Dr Ken Sharpe
Semester: All Year
Credit: 100 points
Prerequisites: as approved by coordinator

BSc (Hons) Applied Statistics

620-493 BSc (Hons) Applied Statistics Research Project
620-494 BSc (Hons) Applied Statistics Advanced Coursework
Coordinator: Dr Ken Sharpe
Semester: All Year
Credit: 100 points
Prerequisites: as approved by coordinator

Applied Statistics advanced coursework:

Students must complete six (6) subjects chosen from those offered through the Key Centre for Statistical Sciences (KCSS) at La Trobe and Monash Universities and RMIT as well as The University of Melbourne. Each subject consists of 24 hours of lectures presented in one 2-hour session per week during either first or second semester. Full details of these subjects are set out in the KCSS booklet that is available from the Mathematics and Statistics department office from mid-October, 2004.

Subject selection requires departmental approval. In some cases, approval may be given to substitute subjects of comparable standard from other areas such as Mathematics and Statistics, Economics and Computer Science.

Coursework Assessment:

The assessment of the Advanced Coursework subject entails assignments (up to 50 pages) and a 2 two-hour written exam for each of the six KCSS subjects. Examinations are held at the end of each semester. All KCSS subjects are of equal weight.

BSc (Hons) Combined Mathematics and Statistics/Physics

620-476	BSc (Hons) Combined Mathematics and Statistics/ Physics Research Project
620-477	BSc (Hons) Combined Mathematics and Statistics/ Physics Coursework
Coordinators:	Associate Professor J.J. Koliha (Mathematics and Statistics) Dr C. T. Chantler (Physics)
Semester:	All Year
Credit:	100 points
Prerequisites:	As approved by the Coordinators

BSC (Hons) Combined Mathematics and Statistics/ Computer Science

620-486	BSc (Hons) Combined Mathematics and Statistics/ Comp Sci Research Project
620-487	BSc (Hons) Combined Mathematics and Statistics/ Comp Sci Coursework
Coordinators:	Associate Professor J.J. Koliha (Mathematics and Statistics) Dr Lee Naish (Computer Science)
Semester:	All Year
Credit:	100 points
Prerequisites:	as approved by the Coordinators

Postgraduate Diplomas in Science

Postgraduate Diplomas in Mathematics & Statistics, and in Applied Statistics are also available. The main differences between these programs and the BSc (Hons) programs are that the entry requirements are not as stringent and it is possible to replace up to two fourth-year courses by third-year ones, subject to approval by the head of department. These programs may be more suitable than the Honours programs for students coming from overseas and for local students who have not majored in Mathematics or Statistics. For more details, please contact either Associate Professor J.J.Koliha or Dr Ken Sharpe.

Australian Mathematical Sciences Institute Summer Subjects

One coursework subject in the Honours program can be replaced by a 24 lecture course offered through the Australian Mathematical Sciences Institute during Summer 2005.

The Australian Mathematical Sciences Institute (AMSI) is a national institute established through a grant from the Victorian Government, and funds from over twenty Australian institutions. For more information about AMSI and full details of the Summer School see the website

http://www.amsi.org.au.

Course Work Timetable

Semester One

Code	*Subject*	*Prerequisites **	*Lecturer*
620-402	Probability for Inference	201	A/Prof Aihua Xia
620-412	Banach and C*-Algebras	311, 312	A/Prof Jerry Koliha
620-413	Complex Analysis	231, 311	Dr Paul Norbury
620-421	Combinatorial Group Theory	321, 322	Dr Lawrence Reeves
620-422	Commutative Algebra	321	A/Prof John Groves
620-426	Algebraic Topology	321, 322	A/Prof Craig Hodgson
620-427	Differential Geometry	321, 322	Dr Kris Wysocki
620-431	Mathematical Biology	331	A/Prof Kerry Landman & A/Prof Barry Hughes
620-432	Computational Mathematics	331+ ability to program	Dr Steve Carnie and Professor Derek Chan
620-442	Phase Transition and Critical Phenomena	620-331	A/Prof Paul Pearce
620-443	Topics in Graph Theory & Enumeration	221 or 252	Prof Tony Guttmann & A/Prof A. Owczarek
620-461	Modelling of Business, Management and Industrial Problems	no strict prereq.	Professor Taylor & A/Profs Boland & Sniedovich
620-462	Integer and Dynamic Programming	no strict prereq.	A/Prof Natashia Boland & A/Prof Moshe Sniedovich
620-471	Linear Mixed Models	371, 372	Dr Meei Ng
620-472	Bioinformatics	see subject descr.	Dr Graham Byrnes
620-474	Consulting and Applied Statistics	371, 372	A/Prof Ian Gordon

Semester Two

Code	*Subject*	*Prerequisites **	*Lecturer*
620-401	Stochstic Optimazation Methods	301	A/Prof Felisa Vazquez-Abad
620-403	Stochastic Processes & their Applications	301	A/Prof Kostya Borovkov
620-411	Morse Theory	322	Prof Hyam Rubinstein
620-423	Algebraic Number Theory	321	Dr David Coulson
620-425	Differential Topology	321, 322	Dr Iain Aitchison
620-433	Advanced Material Modelling	342	A/Prof John Sader and Dr Antoinette Tordesilas
620-441	Integrable Models	221 or 252, 231,232 or 331	Dr Omar Foda
620-444	Topics in Discrete Mathematics	353	Prof Peter Forrester
620-463	Network Optimization	261	Dr Sanming Zhou
620-473	Theory of Statistics	371, 372	A/Prof Ray Watson

* See subject descriptions for additional recommended subjects

Algebra

The methods of modern algebra are important in an enormous variety of mathematical disciplines as well as in many outside mathematics. The algebra group at Melbourne is particularly interested in the theory of groups. A group is an algebraic object that describes the symmetries of something, be it concrete symmetry of a geometric or physical object or the more abstract symmetry that appears in function theory, Galois theory, number theory and physics.

Groups often arise presented by generators and relations. In Combinatorial Group Theory you will learn about such presentations and group theoretic constructions related to them. Although this approach to groups gives powerful structural results, you will also learn how it leads into the realm of formally unsolvable problems!

Commutative Algebra studies the properties of commutative rings and their modules, and is a core tool in many other fields, such as algebraic geometry, and algebraic number theory as well as in group theory and algebraic topology. Depending on interest this course may emphasise the subject as an introduction either to algebraic geometry or to algebraic number theory.

Many branches of mathematics make substantial use of algebraic methods. In Topics in Algebra we will discuss one of these applications of algebra. Possible topics are the classification of semi-simple Lie algebras, algebraic number theory or geometric group theory

Subject: **620-421 Combinatorial Group Theory**
Lecturer: **Dr Lawrence Reeves**
Prerequisites: **620-321, 620-322**
Semester: **1**

Presentations of groups by generators and relations; properties of group theoretic constructions, normal form residual properties, subgroups theory, decision problems.

Subject: **620-422 Commutative Algebra**
Lecturer: **Associate Professor John Groves**
Prerequisite: **620-321**
Semester: **1**

Properties of commutative rings and their modules. The course will usually focus on an application, most often number theory or algebraic geometry. Other applications such as group theory or homological algebra are also possible. The choice of application is open to negotiation.

Subject: **620-423 Algebraic Number Theory**
Lecturer: **Dr David Coulson**
Prerequisite: **620-321**
Semester: **2**

Developing the tools needed to understand unique/non-unique factorization of ideals in the ring of integers of number fields. Hence looking at some of the special cases in which Fermat's last theorem is most easily demonstrated.

Analysis

Subjects offered in this stream introduce students to key theories and important techniques in analysis. They also contain enough background on advanced topics to appeal to those students wishing to specialise in analysis. By the time you finish these courses you will know what makes a theorem beautiful, understand why it is true, and get some idea as to how it is applied.

Banach and C*-algebras belong to Functional Analysis. Over the years they have become indispensable in many parts of mathematics, pure and applied; they have been applied to differential equations, solution of linear systems and numerical mathematics to name a few. A special class of C*-algebras, the famous von Neumann algebras, were introduced to give mathematical foundation of Quantum Mechanics. Von Neumann algebras have been used by Alain Connes to provide a foundation of noncommutative geometry.

In recent years rather close ties have been formed between modern analysis and geometry. In particular, analytical methods of Hamilton and Perelman have been applied to the Ricci flow on Riemannian manifolds to make advances in the solution of the Geometrization Conjecture of Thurston, and in the solution of the Poincare conjecture.

Subject: **620-411 Morse Theory**
Lecturer: **Professor Hyam Rubinstein**
Prerequisites: **620-322**
Semester: **2**

A generalisation of calculus of variations which draws on the relationship between the stationary points of a smooth real-valued function on a manifold and the global topology of the manifold. For example, if a compact manifold admits a function whose only stationary points are a maximum and a minimum, then the manifold is a sphere. There are a number of classical applications of Morse theory, including counting geodesics on a Riemann surface and determination of the topology of a Lie group.

Subject: **620-412 Banach and C*-Algebras**
Lecturer: **Associate Professor Jerry Koliha**
Prerequisites: **620-312**
Semester: **1**

Banach algebras: maximal ideals and the Gelfand representation for commutative algebras. Spectral theory and holomorphic calculus. C*-algebras, Gelfand-Naimark theorem. Compact oprerators and normal operators on Hilbert spaces. Von Neumann algebras.

Subject: **620-413 Complex Analysis**
Lecturer: **Dr Paul Norbury**
Prerequisites: **620-231, 311**
Semester: **1**

Topics include: Homology form of Cauchy's theorem for analytic functions. Cauchy's integral formula. Confirmal mappings and the Riemann mapping theorem. Based on

L. V. Ahlfors, Complex Analysis, McGraw-Hill 1979

Applied Statistics

Four subjects are offered which are essential training for an applied statistician. The subjects include some of the more important and commonly used techniques, the theory behind them as well as detailed examples of their application.

There is much more to applied statistics, but these subjects (in addition to the full range of undergraduate applied statistics courses) provide a solid base of applicable tools for a statistician. An honours graduate with a major in Applied Statistics is in demand: there is an increasing demand for statistical expertise in industry, business and in research science.

In some cases, permission will be given for students to replace one or more of the subjects listed below by subjects from the Applied Statistics Honours program, as offered through the Key Centre for Statistical Sciences. Students interested in pursuing this option should contact Dr Ken Sharpe.

Subject: **620-471 Linear Mixed Models**
Lecturer: **Dr Meei Ng**
Prerequisites: **620-371, 620-372**
Semester: **1**

This course will introduce linear mixed models. Methods of ANOVA, maximum-likelihood (ML) and restricted maximum-likelihood (REML) will be used. Applications to longitudinal data, split-plot designs, repeated measures, etc will be considered.

Subject: **620-472 Bioinformatics**
Lecturer: **Dr Graham Byrnes**
Prerequisites: A sufficient level of mathematical maturity to absorb new skills independently. Probability and statistics at the second year level, and the basic notions of genetics and molecular biology, as presented in any first-year biology course or text.
Semester: **1**

The course is a survey of some applications of probability, statistics and computer science to problems in genetics and molecular biology. Topics will be selected from: random clone libraries and the ordering of cloned DNA fragments and sequence tagged sites; the Sanger method of DNA sequencing, including processing traces, sequence assembly and accuracy; topics in biological sequence analysis, including Markov models of molecular evolution, pairwise and multiple alignment, database searches, and hidden Markov models for the proteins, genes and other features of DNA and protein sequences; methods for the prediction of secondary structure; and inferring phylogenies.

Topics will be illustrated with computational tools available via the internet. Course notes will be available.

Subject: **620-473 Theory of Statistics**
Lecturer: **Associate Professor Ray Watson**
Prerequisites: **620-371, 620-372; 620-374 recommended**
Semester: **2**

Topics selected from: Significance tests; distribution-free methods; point and interval estimation; likelihood methods; Bayesian inference; decision theory; robust methods; sequential analysis.

Subject: **620-474 Consulting and Applied Statistics**
Lecturer: **Associate Professor Ian Gordon**
Prerequisites: **620-371, 620-372; 620-374 recommended**
Semester: **1**

This subject is about the application of statistics in real situations. It deals with thinking about data in a broad context; the client-consultant relationship; consulting sessions; verbal and written communication skills; organizing the structure of a statistical problem; professional ethics; case studies; teamwork; presentation of results including graphical methods, tables, report writing; project work; supervised consulting; developing models; searching the literature for relevant background material; critical assessment.

Discrete Mathematics/Combinatorics

Discrete mathematics and combinatorics are essential subjects for the task of exact computation, whether it be by pen and paper, or by a computer. Underlying exact computations are rich mathematical structures, and one quickly encounters connections with algebra, analysis and geometry. Logical reasoning, a most generic skill in mathematical training, also plays a major role. The popularity of this specialisation on an international level may well be that the questions being asked are well motivated and make good sense, while the answers are as challenging and clever as in any other subject.

Subject: **620-443 Topics in Graph Theory and Enumeration**
Lecturer: **Professor Tony Guttmann and Assoc. Prof. Aleks Owczarek**
Prerequisites: **620-221 or 620-252 or equivalent**
Semester: **1**

The use of generating functions for enumeration of combinatorial structures, including partitions of numbers and of sets, permutations with restricted cycle structure, connected graphs and other types of graph; solution of recurrence relations; methods of asymptotic enumeration; some applications in statistical mechanics.

This course is very general. The methods covered have widespread applicability, including areas of pure and applied mathematics and computer science. It is based on the book 'Generating functionology' by H. S. Wilf.

Subject: **620-444 Topics in Discrete Mathematics**
Lecturer: **Professor Peter Forrester**
Prerequisites: **620-353** (may be waived at the discretion of the lecturer)
Semester: **2**

The study of discrete mathematics complements many other studies in mathematics, both pure and applied. It is a core mathematics subject for all computer science students. In 2003 a 3rd year unit was offered in Discrete Mathematics for the first time. This unit will further build on the main topics studied in that course: enumeration, logical arguments, permutations and finite groups, codes and finite geometry, and physical combinatorics.

Geometry and Topology

Topology relates to the position of objects, for example knotted circles in 3-dimensional space. It is also concerned with the overall structure of spaces, for example if there are holes or singularities. Algebraic topology seeks to convert problems about spaces and mappings between them, into questions in algebra. In Geometry, curvature and distance are studied in spaces like higher dimensional surfaces, which are called manifolds. Manifolds occur naturally in physics, engineering, economics, when one is measuring a number of quantities varying simultaneously.

Geometry and Topology have developed powerful new tools which have been used to solve key problems in other areas of mathematics, such as number theory and dynamical systems. There are important interactions with analysis and algebra. Difficult problems in geometry, such as deformations of metrics and minimisation questions, require non-linear analysis. New invariants in differential geometry and topology have come from topological field theories, suggested by ideas in physics. Geometric concepts such as curvature have been introduced into group theory.

In Geometric topology, ideas are introduced for studying low dimensional manifolds, ie those of dimensions 3 and 4. There are beautiful connections with curvature and polyhedral structures and applications to the active area of knot theory. In Algebraic topology, methods of homology and cohomology theory enable questions about the structures of spaces to be converted into commutative algebra.

Subject: **620-425 Differential Topology**
Lecturer: **Dr Iain Aitchison**
Prerequisites: **620-321, 620-322**
Semester: **2**

Manifold topology in low dimensions: Low-dimensional topology reveals an extremely rich interplay of geometry, analysis, algebra, number theory and models of particles and space-time from physics. We discuss knot theory, its relationships with 2-, 3- and 4-dimensional manifolds, and how recent developments in physics yield new invariants to distinguish knots and 3-dimensional spaces. These concepts are now all the more interesting given Perelman's claimed solution of Thurston's Geometrization Conjecture (hence one of the Clay Prizes). (Some of the ideas developed are currently being investigated in research on bio-polymers, proteins, RNA, DNA, and crystal structures.)

Subject: **620-426 Algebraic Topology**
Lecturer: **Associate Professor Craig Hodgson**
Prerequisites: **620-321, 620-322**
Semester: **1**

Topics selected from: Homology and cohomology of manifolds and duality; homology and cohomology of CW complexes; obstruction theory; homotopy theory; characteristic classes; homological algebra; group homology and cohomology.

Subject: **620-427 Differential Geometry**
Lecturer: **Dr Kris Wysocki**
Prerequisites: **620-321, 620-322**
Semester: **1**

Differential geometry is the study of geometry using methods of differential calculus. The main object is a differentiable manifold. This is a set constructed by gluing together pieces which locally resemble Euclidean space so that one can carry operations of differential calculus. Additional structure, like Riemannian metric, provides us with concepts of length, volume, and notions of curvature. The course will introduce basic concepts of differential geometry. The topics covered will include: surfaces, differential manifolds, tangent bundle, vector fields, Riemannian metric, connections, curvature and geodesics.

Mathematical Physics and Statistical Mechanics

Physics has provided major impetus for the development of novel mathematics for the past thousand years at least! Mathematical physics is a broad subject covering every area of mathematics and physics. In the units here integrable dynamical systems and statistical mechanics, both of which have been foci of mathematical physics in the past hundred years, are explored. Studying these units will bring one into a voyage of discovery with unexpected connections between different areas of mathematics including differential equations, probability theory, algebra and group theory.

Subject: **620-441 Integrable Models**
Lecturer: **Dr Omar Foda**
Prerequisites: **620-221 or 252, 231, 232 or 331**
Semester: **2**

An introduction to integrable models using the KdV equation as a rich, but relatively elementary example, with emphasis on the inverse scattering transform as the analogue of Fourier/Laplace transforms for nonlinear partial differential equations. Topics include: • The initial value problem for KdV equation and one soliton solutions. • The Lax representation and Sturm-Liouville problem. • Inverse scattering and the Gelfand-Levitan equation. • Hirota's equation and multisoliton solutions. • Pseudodifferential operators and the KdV hierarchy. • Zakharov-Shabat formulation and Zero-curvarture method.

If time permits one of the two following topics may be discussed:
A. Algebraic geometric solutions of periodic KdV.
B. KP and higher rank analogues of KdV.

Subject: **620-442 Phase Transitions and Critical Phenomena**
Lecturer: **Associate Professor Paul Pearce**
Prerequisites: **620-331** (maybe waived at the discretion of the lecturer)
Semester: **1**

Gibbs ensembles in statistical mechanics, the thermodynamic limit, ideal gas, Tonks and van der Waals gasses, spin chains, mean-field theories of fluids and ferromagnets, phase transitions, critical exponents, universality and scaling. Exactly solvable lattice models: Yang-Baxter equations, duality, inversion relations, commuting row transfer matrices, solution of two-dimensional lattice spin models.

Although it looks like a lot of material on solvable lattice models, in fact only the last 4 of the 24 lectures are devoted to this material.

Methods and Modelling

The subjects offered under this section are designed to provide students with experience in defining and formulating problems in a variety of applications and with skills to develop relevant quantitative solutions of these problems. We believe these are important academic and professional attributes for Honours students to acquire whether they intend to enter the workplace or to continue with postgraduate studies.

The subjects on offer serve as basic training in applied mathematics for students with a strong background and interest in mathematics but perhaps have limited experience in mathematical modelling, approximation and computation. You will have the opportunity to learn how to:

• formulate a well-posed problem in mathematical terms from a possibly sketchy description

• carry out necessary mathematical analysis which may require exact treatment or reasonable approximate methods

• develop appropriate numerical methods to obtain quantitative results using software packages and/or writing computer code

• interpret the results and where necessary refine the original model

While the mathematical techniques and topics have broad applications, the specific topics are guided by the research interests and expertise of members of the Continuum Modelling Group. Our research covers areas in colloid science, developmental biology, chemical engineering and materials science. The research is motivated and supported by our association with the Particulate Fluids Processing Centre (a Special Research Centre funded by the Australian Research Council), the Royal Childrens' Hospital and the US Army Research Agency. Specific interest and strengths are in the areas of mechanics of granular media, contact mechanics of deformable bodies such as liquid drops and emulsions, mechanical, electrical and optical properties of nano-particles, the proliferation and movement of cells in embryonic development and random walks, random networks and random environments.

Subject: **620-431 Mathematical Biology**
Lecturer: **Associate Professors Kerry Landman and Barry Hughes**
Prerequisites: **620-331**
Semester: **1**

Modern techniques have revolutionised biology and medicine, but interpretative and predictive tools are needed. Mathematical modelling is such a tool. It provides explanations for counter-intuitive results and predictions leading to new experimental directions. Mathematical techniques are beginning to play a key role in tackling challenges in the medical sciences. This subject will use discrete and continuum techniques to model the migration of individual cells and cell populations Applications will be drawn from animal pattern formation, tumour growth, developmental biology and tissue engineering. The techniques covered will include some of partial differential equations, stability and perturbation techniques, random walk processes, evolving networks, random spatial structures, transforms, generating functions, asymptotic methods and simulation. Assessment is by assignment and exam.

Subject: **620-432 Computational Mathematics (Honours)**
Lecturer: **Dr Steven Carnie and Professor Derek Chan**
Prerequisites: **620-331** and ability to program in something, eg C, Matlab, Mathematica, Perl, Fortran
Semester: **1**

In Computational Mathematics you will learn how to write and implement numerical solutions to a variety of problems commonly encountered in science and engineering. Understanding the behaviour of the mathematical problem gives insight into the pitfalls for the unwary in using canned packages inappropriately or uncritically.

The subject will cater for students who have done 620-381 (or equivalent), as well as those who have not. Topics will be selected from: solving an algebraic equation, solving linear and nonlinear systems of equations, solving initial value problems for ordinary differential equations, stiff solvers, differential-algebraic equations (DAE), boundary value problems for ordinary differential equations (by shooting methods and relaxation) and the solution of parabolic, hyperbolic and elliptic partial differential equations or other topics, based on the interests of students. Assessment is by assignments and an oral presentation. Students will be expected to use Matlab for their assignments.

Subject: **620-433 Advanced Materials Modelling**
Lecturer: **Associate Professor John Sader and Dr Antoinette Tordesillas**
Prerequisites: **620-342**
Semester **2**

This subject focuses on physical principles and techniques for modelling the behaviour of advanced materials, which find applications in modern technological advances ranging from nanoelectromechanical (NEMS) systems and Atomic Force Microscopy to processes in the pharmaceutical industry involving the manipulation of fine powders and grains. Particular attention will be paid to development of continuum techniques and discrete models for describing the deformation and mechanical behaviour of elastic bodies and granular materials. As such, this subject will draw directly on fundamental knowledge gained by students in the field of fluid mechanics (620-342). Topics to be covered include basic properties of granular flow, friction, dilatation, mixing and segregation, and fundamentals of elastic deformation including indentation, deformation of beams and plates and variational principles governing their behaviour. Advanced mathematical techniques will also be introduced enabling both exact and approximate solutions. Assessment will be by examination and assignment.

Operations Research

In undergraduate operations research, the focus was on basic methods, modelling real-world problems, and problem-solving. The Honours subjects in operations research are all about getting to the guts of the matter; they are about understanding at a deeper level both the modelling and the mathematics of operations research.

They also take you beyond the linear, linear integer and convex non-linear models that you would have seen as an undergraduate, into a much richer realm, from parametric problems, to infinite dimensional problems (optimal control problems), to combinatorial problems and to much more general ideas about underlying concepts such as convexity. You will also have the opportunity to work on the formulation and analysis of applied stochastic models, and to explore the relationship between these models and the optimization techniques you have discussed elsewhere.

These subjects will take you to the edge; you will see where new research is happening, get an angle on unresolved issues, see where the open problems lie. These courses provide a launching pad into research in operations research, in both the academic and commercial worlds.

Subject: **620-461 Modelling of Business, Management and Industrial Problems**
Lecturer: **ProfessorTaylor and Assoc/Professors Boland and Sniedovich**
Prerequisites: No strict prerequisites
Semester: **1**

The main thrust of this subject is the art and science of applied mathematical modelling. Although the subject will be problem-driven, it will cover in a systematic way the foundations of four distinct (yet obviously related) modelling paradigms:

• Integer Programming

• Sequential Decision Processes

• Networks

• Stochastic Processes

This subject offers an excellent opportunity to non-OR students to gain useful generic OR skills.

Subject: **620-462 Integer and Dynamic Programming**
Lecturer: **Assoc/Professors Natashia Boland and Moshe Sniedovich**
Prerequisites: **620-362 recommended**
Semester: **1**

• A tour of modern integer programming techniques, including polyhedral theory, branch-and-bound methods, cutting plane methods, valid combinatorial inequalities, and alternative relaxations and duals such as the Lagrangian relaxation and Lagrangian dual.

• A very gentle introduction to the art of and science of sequential decision-making including the theoretical and algorithmic aspects of dynamic programming and their applications in the context of practical problems.

Subject: **620-463 Network Optimization**
Lecturer: **Dr Sanming Zhou**
Recommended: **620-261; 352 and 362 recommended**
Semester: **2**

Network optimization problems arise from a diversity of areas such as Industry, Management, VLSI Layout, Transportation, Telecommunication, Computer Networking, Information Processing, etc. This subject is an introduction to Network Optimization with focus on important ideas, theoretical results and algorithms. It covers classical problems that can be solved in polynomial-time, and some more difficult (NO-hard) problems for which polynomial-time algorithms are unlikely to exist. Topics are selected from: Problems and Algorithms, Minimum Spanning Trees, Shortest Paths, Maximum Flows, Minimum Cost Flows, Multicommodity flows, Maximum Matching and Assignment Problems, Matroids and Greedy Algorithms, Computational Complexity, and Approximation Algorithms.

References:

[1] W. J. Cook, W. H. Cunningham, W. R. Pulleyblankand A. Schrijver, Combinatorial Optimization, John Wiley & Sons, Inc., New York, 1998.

[2] B. Korte, J. Vygen, Combinatorial Optimization: Theory and Algorithms, Springer-Verlag, Berlin, 2000.

[3] R. K. Ahuja, T. L. Magnanti, J. B. Orlin, Network Flows: Theory, Algorithms, and Applications, Prentice Hall, Inc., Englewood Cliffs, NJ, 1993.

[4] J. R. Evans, E. Minieka, Optimization Algorithms for Networks and Graphs, 2nd ed., Marcel Dekker, Inc., New York, 1992.

Probability and Stochastic Processes

Almost every phenomenon in the world – be it of a physical, social, medical, or financial nature - involves a degree of randomness. Therefore to understand many phenomena it is necessary to understand randomness. Theory of stochastic (or random) processes is part of mathematics describing systems that evolve randomly in time or space. It has applications in various areas and enables one to answer such diverse questions as:

• how to decide on the capacity necessary for a computer network to perform adequately;
• how to decode the DNA sequence on the human genome;
• how to describe the properties of a series of counts of radioactive emissions;
• how to price an option on a financial market.

In the courses described in this section of the Guide, you will learn:

• the formalities of a rigorous understanding of stochastic processes;
• techniques for calculating important characteristics of different stochastic processes;
• limiting distributions arising in standard situations and their applications;
• the application of stochastic processes to many different problems.

In Probability for Inference the basic techniques of modern probability which are useable in statistical inference are described. Examples of applications of these techniques are provided.

In Stochastic Processes and Applications such techniques are used to lay the foundations of the theory of stochastic processes and then to study a number of the basic models of stochastic processes. We also discuss applications of the theory in a variety of situations.

Subject: **620-401 Stochastic Optimization Methods**
Lecturer: **Associate Professor Felisa Vazquez-Abad**
Prerequisite: **620-301; 620-302 recommended**
Semester: **2**

Markov Chain Monte Carlo and simulated annealing. Discrete and continuous optimization methods in stochastic environment (search methods, Q-learning, gradient-based methods, etc). Convergence analysis for off-line optimization and on-line learning.

Subject: **620-402 Probability for Inference**
Lecturer: **Associate Professor Aihua Xia**
Prerequisites: **620-201; 620-301 and 620-302 recommended**
Semester: **1**

Probability spaces and random variables, a measure theoretical approach. Expectation and conditional expectation, distribution-free and distribution-based approaches with applications to mean square estimation and to sufficient statistics. Modes of convergence and limit theorems with applications to estimation and hypothesis testing.

References:
Hogg and Craig (1970) *Introduction to Mathematical Statistics*, Macmillan, 3rd ed.
Billingsley (1986) *Probability and Measure*, Wiley Series in Probability and Mathematical Statistics.
Shiryayev (1984) *Probability*, Graduate Texts in Mathematics Springer-Verlag.

Subject: **620-403 Stochastic Processes and their Applications**
Lecturer: **Associate Professor Kostya Borovkov**
Prerequisite: Second year probability and some second year mathematics; **620-301; and 620-302 recommended**
Semester: **2**

Basic concepts of the theory of stochastic processes. Finite dimensional distributions and path properties. Convergence of stochastic processes and Skorokhod theorem. Theory of martingales with applications. Processes with independent increments. Markov processes. Applications to modelling throughout the course.

References:
Ross, S.M (1996) *Stochastic Processes*. Wiley, New York.
Grimmett, G.R. and Stirzaker, D.R. (1981) *Probability and Random Processes*. Clarendon Press, Oxford.

BSc (Hons) in Mathematics and Statistics

PROPOSED COURSE DETAILS 2005

Please return this form to Associate Professor J. J. Koliha by 15th January 2005.

Name:____

Student Number:________________

Email address(es):____

Preferred contact tel. no. (mobile if you like): ____________________________

Status: Part time ❑ Full time ❑

Combined: Physics ❑ Comp. Sci. ❑

Proposed Course Details *at least 6 to be chosen*:

Semester 1	Semester 2

Enter all subjects including subjects offered by other Departments and/or AMSI; these should have been previously discussed with the Coordinator.

Project Supervisor (make contact by end of December 2004):

....

Project Title (if available):

....

BSc (Hons) in Applied Statistics
PROPOSED COURSE DETAILS 2005

Please return this form to Dr Ken Sharpe by 15th January 2005.

Name:____

Student Number:________________

Email address(es):____

Preferred contact tel. no. (mobile if you like): _____________________________

Status? Part time ❑ Full time ❑

Coursework Units from KCSS booklet (and Maths & Stats honours courses) – *at least 6 to be chosen*:

Semester 1	Semester 2

Project Supervisor (make contact by end of December 2004):

....

Project Title (if available):

....