THE UNIVERSITY OF ADELAIDE AUSTRALIA

School of Mathematical Sciences

Level II and III Courses in 2012

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This document provides information about the level II and level III courses offered in the School of Mathematical Sciences at the University of Adelaide during 2012. It is intended to assist students in choosing their subjects by providing a short, readable description for courses available at level II or III in either Applied Maths (APP MTH), Pure Mathematics (PURE MTH) or Statistics (STATS)[1].

Further details including detailed course content and contact hours can be obtained from the University of Adelaide Calendar and Course Planner.

Please note that you are welcome —indeed, very much encouraged— to discuss your subject choices for next year with any of your Mathematics or Statistics lecturers, or with one of the School's Course Advisors.

[1]A current version of this document in PDF format is always available from the School's web site: http://www.maths.adelaide.edu.au/students/undergraduate.html

Summary of Courses

Level II			
Course Name	**Code**	**Semester**	**Units**
Algebra	PURE MTH 2106	1	3
Differential Equations	MATHS 2102	1	3
Multivariable & Complex Calculus	MATHS 2101	1	3
Probability & Statistics	MATHS 2103	1	3
Numerical Methods	MATHS 2104	2	3
Optimisation and Operations Research	APP MTH 2105	2	3
Real Analysis	MATHS 2100	2	3
Statistical Modelling and Inference	STATS 2107	2	3

Level III			
Course Name	**Code**	**Semester**	**Units**
Applied Probability III	APP MTH 3001	1	3
Complex Analysis III	PURE MTH 3019	1	3
Computational Mathematics III	APP MTH 3000	1	3
Differential Equations III	APP MTH 3013	1	3
Groups & Rings III	PURE MTH 3007	1	3
Mathematical Statistics III	STATS 3006	1	3
Number Theory III	PURE MTH 3003	1	3
Optimisation III	APP MTH 3014	1	3
Statistical Modelling III	STATS 3001	1	3
Topology & Analysis III	PURE MTH 3002	1	3
Waves III	APP MTH 3017	1	3
Biostatistics III	STATS 3008	2	3
Coding & Cryptology III	PURE MTH 3018	2	3
Communication Skills III	MATHS 3015	2	3
Fields & Modules III	PURE MTH 3023	2	3
Finite Geometry III	PURE MTH 3024	2	3
Financial Modelling: Tools and Techniques	APP MTH 3012	2	3
Fluid Mechanics III	APP MTH 3002	2	3
Integration & Analysis III	PURE MTH 3009	2	3
Mathematical Biology III	APP MTH 3004	2	3
Random Processes III	APP MTH 3016	2	3
Sampling Theory and Practice III	STATS 3003	2	3
Time Series III	STATS 3005	2	3
Variational Methods and Optimal Control III	APP MTH 3010	2	3

Course Descriptions

Algebra

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Knowledge of group theory and of linear algebra is important for an understanding of many areas of pure and applied mathematics, including advanced algebra and analysis, number theory, coding theory, cryptography and differential equations. There are also important applications in the physical sciences.

Applied Probability III

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Many processes in the real world involve some random variation superimposed on a deterministic structure. Often – as in games – the random component is the dominant part. This course aims to provide a basic toolkit for modelling and analyzing discrete—time problems in which there is a significant probabilistic component. Markov chain examples in the course include population branching processes (with application to genetics), random walks (with application to tennis and other games), and processes with an over–riding cost structure.

Biostatistics III

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Biostatistics is the branch of statistics developed for applications within the biomedical, pharmaceutical and health sciences. These methods are fundamental to contemporary medical research. They play a key role in evaluating treatments for diseases such as cancer and heart disease, in predicting the spread and incidence of epidemics and in evaluating the risk associated with factors such as obesity or exposure to electromagnetic radiation. This course provides an introduction to the design and analysis of clinical trials and epidemiological studies, and methods for the analysis of biostatistical data.

Coding & Cryptology III

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The fundamental objective of cryptology is to enable communication over an insecure channel in such a way that an eavesdropper cannot understand what is being said. Classical cryptosystems required participants to share a common key. The new public key systems removed the need to share a private key. Coding theory is concerned with finding efficient schemes by which digital information can be coded for reliable transmission through a noisy channel. Error correcting codes are widely used in applications such as transmission of pictures from deep space, storage of data on CDs and design of identification numbers.

Communication Skills III

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In the modern world, skill at communicating mathematics is sometimes just as important as skill at doing mathematics. This course develops students' skills in both the written and verbal communication of mathematics. In addition the general communication skills which are fundamental to getting and keeping a job are taught. The course encourages student learning with a range of interesting teaching techniques, including guest lecturers and workshops.

Complex Analysis III

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When the real numbers are replaced by the complex numbers in the definition of the derivative of a function, the resulting (complex-)differentiable functions turn out to have many remarkable properties not enjoyed by their real analogues. These functions, usually known as holomorphic functions, have numerous applications in areas such as engineering, physics, differential equations and number theory, to name just a few. The focus of this course is on the study of holomorphic functions and their most important basic properties.

Computational Mathematics III

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In exploring large scale, complex systems, physicists, engineers, financiers and mathematicians often formulate problems as partial differential equations or many coupled ordinary differential equations. Only rarely can these mathematical models be solved algebraically. Instead computational mathematics derives approximate models that form the basis of computer predictions. Such models predict the climate, the weather, option prices, industrial processes, engineering devices, blood flow, epidemiology and more. This course develops sound stable computational methods for exploring large-scale systems.

Differential Equations

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Most “real life” systems that are described mathematically, be they physical, financial, economic or some other kind, are described by means of differential equations. Our ability to predict the way in which these systems evolve or behave is determined by our ability to find solutions of these equations explicitly or to be able to approximate solutions as accurately as we need. Every differential equation presents its own challenges, but there are various classes of differential equations, and for some of these there are established approaches and methods for solving them. This course presents some of the most important such methods.

Differential Equations III

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Differential equations describe a wide range of practical problems in areas such as biology, engineering, physical sciences, economics and finance. This course aims to provide students with techniques required to solve classes of ordinary and partial differential equations that commonly occur in applications.

Fields & Modules III

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This subject presents the foundational material for the last of the basic algebraic structures pervading contemporary pure mathematics, namely fields and modules. The basic definitions and elementary results are given, followed by two important applications of the theory: to the classification of finitely generated abelian groups, and to Jordan canonical form for matrices. The subject concludes by returning to fields to present interesting applications of the theory.

Finite Geometry III

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Projective geometry is one of the important modern geometries introduced in the 19th century. Projective geometry is more general than our usual Euclidean geometry, and it has useful applications in Information Security, Statistics, Computer Graphics and Computer Vision. The majority of this course will be on projective planes.

Financial Modelling: Tools and Techniques

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The growth of the range of financial products that are traded on financial markets or are available at other financial institutions, is a notable feature of the finance industry. A major factor contributing to this growth has been the development of sophisticated methods to price these products. The significance to the finance industry of developing a method for pricing options (financial derivatives) was recognized by the awarding of the Nobel Prize in Economics to Myron Scholes and Robert Merton in 1997. The mathematics upon which their method is built is stochastic calculus in continuous time. Binomial lattice type models provide another approach for pricing options. These models are formulated in discrete time and the examination of their structure and application in various financial settings takes place in a mathematical context that is less technically demanding than when time is continuous. This course discusses the binomial framework, shows how discrete-time models currently used in the financial industry are formulated within this framework and uses the models to compute prices and construct hedges to manage financial risk. Spreadsheets are used to facilitate computations where appropriate.

Fluid Mechanics III

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Fluid flows are important in many scientific and technological problems including atmospheric and oceanic circulation, energy production by chemical or nuclear combustion in engines and stars, energy utilisation in vehicles, buildings and industrial processes, and biological processes such as the flow of blood. Considerable progress has been made in the mathematical modelling of fluid flows and this has greatly improved our understanding of these problems, but there is still much to discover. This course introduces students to the mathematical description of fluid flows and the solution of some important flow problems.

Groups & Rings III

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The algebraic notions of groups and rings are of great interest in their own right, but knowledge and understanding of them is of benefit well beyond the realms of pure algebra. Areas of application include, for example, advanced number theory; cryptography; coding theory; differential, finite and algebraic geometry; algebraic topology; representation theory and harmonic analysis including Fourier series. The theory also has many practical applications including, for example, to the structure of molecules, crystallography and elementary particle physics.

Integration & Analysis III

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The Riemann integral works well for continuous functions on closed bounded intervals, but it has certain deficiencies that cause problems, for example, in Fourier analysis and in the theory of differential equations. To overcome such deficiencies, a "new and improved" version of the integral was developed around the beginning of the twentieth century, and it is this theory with which this course is concerned. The underlying basis of the theory, measure theory, has important applications not just in analysis but also in the modern theory of probability.

Mathematical Biology III

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The application of mathematics to problems arising in the life sciences is a rapidly growing area yielding quantitative understanding of questions about such things as the spread of infectious diseases, population growth and interaction, organ (e.g. heart) function, cell signalling, nutrient supply, and more. This course will introduce students to the fascinating world of modelling biological systems. A variety of biological problems will be considered, in the context of which students will be exposed to a variety of mathematical techniques. No previous exposure to biology is necessary.

Mathematical Statistics III

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Statistical methods used in practice are based on a foundation of statistical theory. One branch of this theory uses the tools of probability to establish important distributional results that are used throughout statistics. Another major branch of statistical theory is statistical inference. It deals with issues such as how do we define a "good" estimator or hypothesis test, how do we recognise one and how do we construct one? This course is concerned with the fundamental theory of random variables and statistical inference.

Multivariable & Complex Calculus

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The mathematics required to describe most "real life" systems involves functions of more than one variable, so the differential and integral calculus developed in a first course in Calculus must be extended to functions of more variables. In this course, the key results of one-variable calculus are extended to higher dimensions: differentiation, integration, and the link between them provided by the Fundamental Theorem of Calculus are all generalised. The machinery developed can be applied to another generalisation of one-variable Calculus, namely to complex calculus, and the course also provides an introduction to this subject. The material covered in this course forms the basis for mathematical analysis and application across an extremely broad range of areas, essential for anyone studying the hard sciences, engineering, or mathematical economics/finance.

Number Theory III

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Number theory is one of the oldest branches of mathematics. It is concerned with the properties of numbers, especially the properties of the integers. Historically, it was valued as the purest form of mathematics, but in fact there are many modern applications to information technology and cryptography. Number theory is a fundamentally useful course for any mathematician, but it also attracts a general audience because of its intrinsic beauty and its emphasis on problem-solving.

Numerical Methods

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To explore complex systems, physicists, engineers, financiers and mathematicians require computational methods since mathematical models are only rarely solvable algebraically. Numerical methods, based upon sound computational mathematics, are the basic algorithms underpinning computer predictions in modern systems science. Such methods include techniques for simple optimisation, interpolation from the known to the unknown, linear algebra underlying systems of equations, ordinary differential equations to simulate systems, and stochastic simulation under unknown influences.

Optimisation and Operations Research

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Operations Research (OR) is the application of mathematical techniques and analysis to problem solving in business and industry, in particular to carrying out more efficiently tasks such as scheduling, or optimising the provision of services. OR is an interdisciplinary topic drawing from mathematical modelling, optimisation theory, game theory, decision analysis, statistics, and simulation to help make decisions in complex situations. This first course in OR concentrates on mathematical modelling and optimisation: for example maximising production capacity, or minimising risk. It focuses on linear optimisation problems involving both continuous, and integer variables. The course covers a variety of mathematical techniques for linear optimisation, and the theory behind them. It will also explore the role of heuristics in such problems. Examples will be presented from important application areas, such as the emergency services, telecommunications, transportation, and manufacturing. Students will undertake a team project based on an actual Adelaide problem.

Optimisation III

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Most problems in life are optimisation problems: what is the best design for a racing kayak, how do you get the best return on your investments, what is the best use of your time in swot vac, what is the shortest route across town for an emergency vehicle, what are the optimal release rates from a dam for environmental flows in a river? Mathematical formulations of such optimisation problems might contain one or many independent variables. There may or may not be constraints on those variables. There is always, though, an objective: minimise or maximise some function of the variable(s), subject to the constraints. This course will examine nonlinear mathematical formulations, and will concentrate on convex optimisation problems. Many modern optimisation methods in areas such as design of communication networks, finance, etc, rely on the classical underpinnings covered in this course.

Probability & Statistics

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Probability theory is the branch of mathematics that deals with modelling uncertainty. It is important because of its direct application in areas such as genetics, finance and telecommunications. It also forms the fundamental basis for many other areas in the mathematical sciences including statistics, modern optimisation methods and risk modelling. This course provides an introduction to probability theory, random variables and Markov processes.

Real Analysis

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The underlying theme for this course is that of convergence. It is very rare to find a "real–life" problem that can be solved exactly, and the best we can usually do is to make approximations. If such approximations can be made arbitrarily well, we are confronted with the issue of a sequence of some kind and its convergence. In this regard, Real Analysis provides students with a deeper understanding of the real numbers and continuous functions of a real variable. It forms the theoretical foundations for much of analysis, and has applications in parts of Applied Mathematics, Science, Engineering and Finance.

Sampling Theory and Practice III

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Sample surveys are an important source of statistical data. A great many published statistics on demographic, economic, political and health related characteristics are based on survey data. Simple random sampling is a well known method of sampling but, for reasons of efficiency and practical constraints, methods such as stratified sampling and cluster sampling are typically used by statistical authorities such as the Australian Bureau of Statistics and by market research organisations. This course is concerned with the design of sample surveys and the statistical analysis of data collected from such surveys.

Statistical Modelling and Inference

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Statistical methods are important to all areas that rely on data including science, technology, government and commerce. To deal with the complex problems that arise in practice requires a sound understanding of fundamental statistical principles together with a range of suitable modelling techniques. Computing using a high level statistical package is also an essential element of modern statistical practice. This course provides an introduction to the principles of statistical inference and the development of linear statistical models with the statistical package R.

Statistical Modelling III

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One of the key requirements of an applied statistician is the ability to formulate appropriate statistical models and then apply them to data in order to answer the questions of interest. Most often, such models can be seen as relating a response variable to one or more explanatory variables. For example, in a medical experiment we may seek to evaluate a new treatment by relating patient outcome to treatment received while allowing for background variables such as age, sex and disease severity. In this course, a rigorous discussion of the linear model is given and various extensions are developed. There is a strong practical emphasis and the statistical package R is used extensively.

Random Processes III

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This course introduces students to the fundamental concepts of stochastic modelling with an emphasis on applications relating to telecommunication systems. Considerable emphasis is also placed on the development of skills, which are important in the workplace. Amongst these are presentation and communication skills, ability to present a solution in terms that the "owner of a problem" can understand, and ability to make decisions about which techniques might be useful to solve a problem. Application of the above skills to sophisticated models of telecommunications systems are developed by students through completing a series of mini-projects.

Time Series III

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Time series consist of values of a variable recorded over a long period of time. Such data arise in just about every area of science and the humanities, including econometrics and finance, engineering, medicine, genetics, sociology, environmental science. What makes time series data special is the presence of dependence between observations in a series, and the fact that usually only one observation is made at any given point in time. This means that standard statistical methods are not appropriate, and special methods for statistical analysis are needed. This course provides an introduction to time series analysis using current methodology and software.

Topology & Analysis III

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Solving equations is a crucial aspect of working in mathematics, physics, engineering, and many other fields. These equations might be straightforward algebraic statements, or complicated systems of differential equations, but there are some fundamental questions common to all of these settings: does a solution exist? If so, is it unique? And if we know of the existence of some specific solution, how do we determine it explicitly or as accurately as possible? This course develops the foundations required to rigorously establish the existence of solutions to various equations, thereby laying the basis for the study of solutions. Through an understanding of the foundations of analysis, we obtain insight critical in numerous areas of application, such areas ranging across physics, engineering, economics and finance.

Variational Methods & Optimal Control III

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Many problems of optimisation and control in science and engineering seek to find the shape of a curve or surface satisfying certain conditions so as to maximise or minimise some quantity. For example, design the shape of a yacht hull so as to minimise fluid drag, or control the flight trajectory of a rocket to maximize the height it can attain. Variational methods involve an extension of calculus to handle such problems. This course develops an appropriate methodology, illustrated by a variety of physical and engineering problems.

Waves III

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Waves impact on every facet of our experience. The simple acts of seeing and hearing rely on electromagnetic and sound waves. Traffic flows in waves. Earthquakes and tsunamis are waves capable of causing enormous devastation. Waves carry the information required for our technological society to function. This course will introduce you to the study of waves through a wide variety of examples of wave motions.