MA501 Statistics for Insurance

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	100% Exam	Wang Dr X
1	Canterbury	Spring	I	15 (7.5)	90% Exam, 10% Coursework	Wang Dr X

Contact Hours

32 lectures, 3 example classes (1 hour each)

Learning Outcomes

The Intended Subject Specific Learning Outcomes. On successful completion of the module students will be able to:
- explain basic concepts and models in decision analysis and statistics, as presented in the module, and apply them in insurance;
- construct risk models appropriate to short term insurance contracts and make the relevant inference;
- describe and apply the fundamental concepts of creditbility theory;
- describe and apply the basic methodology used in rating general insurance business;
- describe and apply techniques for analysing a delay (or run-off) triangle;

The Intended Generic Learning Outcomes. One successful completion of the module, students will:
- be able to demonstrate probabilistic and statistical skills in solving financial problems;
- have enhanced their conceptual skills and logical reasoning abaility;
- demonstrate a broad understanding of the range of application of statistics to financial processes.

Method of Assessment

90% Examination, 10% Coursework

Preliminary Reading

The students are provided with the study notes published by the Actuarial Education Company and a copy of "Formulae and Tables for Examinations".

The following book is also relevant:
PJ Boland Statistical and Probabilistic Methods in Actuarial Science (Chapman & Hall, 2007) (R)

Pre-requisites

MA629 Probability and Inference or MA529 Probability and Statistics for Actuarial Science 2

Synopsis *

This module covers aspects of Statistics which are particularly relevant to insurance. Some topics (such as risk theory and credibility theory) have been developed specifically for actuarial use. Other areas (such as Bayesian Statistics) have been developed in other contexts but now find applications in actuarial fields. Stochastic processes of events such as accidents, together with the financial flow of their payouts underpin much of the work. Since the earliest games of chance, the probability of ruin has been a topic of interest. Outline Syllabus includes: Decision Theory; Bayesian Statistics; Loss Distributions; Reinsurance; Credibility Theory; Empirical Bayes Credibility theory; Risk Models; Ruin Theory; Generalised Linear Models; Run-off Triangles.

Marks on this module can count towards exemption from the professional examination CT6 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA509 Actuarial Practice

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn and Spring	H	30 (15)	50% Coursework, 50% Exam	Jackson Mr A

Contact Hours

72 timetabled hours, comprising lectures, workshops and seminars

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the module, students will be able to:
a) describe the main types of financial services encountered in actuarial work;
b) discuss the different roles undertaken by actuaries and the core skills required in each practice area;
c) describe how the design of financial services impacts on the risks for the various stakeholders;
d) discuss the application of actuarial science in the context of the general business, social and legal environment;
e) discuss sources of risk to providers of financial services;
f) describe how providers of financial services can manage risks;
g) discuss topical issues relevant to the financial services industry.

The intended generic learning outcomes. On successful completion of the module, students will have developed
a) improved communication skills;
b) enhanced intellectual independence;
c) relevant computing skills, including the use of appropriate document preparation software;
d) improved problem solving skills;
e) awareness of important issues relating to good oral and written presentation of results;
f) greater ability to select material from source texts, found independently or through recommendation; and awareness of the relationship of this material to background and more advanced material;
g) independent learning and time management skills;
h) improved teamwork skills;
i) ability to reflect and an understanding of actions required for career development.

Method of Assessment

50% Examination, 50% Coursework

Preliminary Reading

Bellis C, Lyon R, Klugman S and Shepherd J (editors) Understanding Actuarial Management (2nd ed. Institute of Actuaries of Australia and Society of Actuaries, 2010)
Haberman S, Booth P, Chadburn R, James D, Khorasanee Z, Plumb R and Rickayzen B Modern Actuarial Theory and Practice (2nd ed. Chapman & Hall/CRC, 2005)

Pre-requisites

MA516 Contingencies I

Synopsis *

This module covers the entry-level skills and knowledge required for those wishing to enter the actuarial (or related) profession. The module provides context for the actuarial techniques learned to date on the programme, as well as providing a platform for ongoing professional development. The first half of the module focuses on employability-related topics, such as creating a strong CV, and how to succeed in assessment centres. The second half explores the sectors that actuaries typically work in, explaining the concepts underpinning life insurance, general insurance, pensions, and risk management. Because of its practical nature, the syllabus is dynamic, changing regularly to reflect current practice and trends.

The textbooks listed are not required to be purchased, but may be consulted as further reading for students.

MA516 Contingencies 1

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Wood Mr N

Contact Hours

48 hours of Lectures and Examples classes.

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the module students will be able to:
a) Define simple assurance and annuity contracts, and develop formulae for the means and variances of the present values of the payments under these contracts, assuming constant deterministic interest.
b) Obtain expressions in the form of sums/integrals for the mean and variance of the present value of benefit payments under each contract above including cases where premiums are payable more frequently than annually and that benefits may be payable annually or more frequently than annually.
c) Describe practical methods of evaluating expected values and variances of the simple contracts defined in objective a.
d) Describe and calculate, using ultimate or select mortality, net premiums and net premium provisions of simple insurance contracts.
e) Carry out the above for simple insurance contracts involving two lives.

The intended generic learning outcomes. On successful completion of the module students will:

a) have developed a logical mathematical approach to solving problems;
b) have developed skills in written communication, time management and organisation and studying.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

The study notes published by the Actuarial Education Company are recommended. Instructions on how to obtain the notes will be given in class.

The following may be consulted for background reading, but are not required reading.
NL Bowers, HU Gerber, JC Hickman et al. Actuarial mathematics. 2nd ed. Society of Actuaries, 1997. ISBN: 0938959468
WF Scott Life assurance mathematics, Heriot-Watt University, 1999.
Neill, A. Heinemann Life contingencies., 1977. ISBN: 0434914401
HU Gerber Life insurance mathematics. 3rd ed. Springer; Swiss Association of Actuaries, 1997. ISBN: 354062242X

Pre-requisites

MA315 Financial Mathematics, MA319 Probability & Statistics for Actuarial Science, or equivalent.

Synopsis *

This module introduces the concept of survival models, which model future survival time as a random variable. The concept is combined with the financial mathematics learned in module MA315, making it possible to analyse simple contracts which depend on survival time, such as life insurance and annuities. The syllabus will cover: introduction to survival models including actuarial notation, allowance for temporary initial selection and an overview of the typical pattern of human mortality; formulae for the means and variances of the present values of payments under life insurance and annuity contracts assuming constant deterministic interest; practical methods for evaluating the formulae; description and calculation of net premiums, net premium provisions and mortality profit or loss under simple life insurance and annuity contracts; and extension of the basic concepts to straightforward contracts involving two lives.

Marks on this module can count towards examption from the professional examination CT5 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA517 Corporate Finance for Financial Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Bevan Mr R

Contact Hours

48 (24 lectures and 24 example classes/supervised problem solving sessions)

Learning Outcomes

The intended subject specific learning outcomes:
On successful completion of this module students will have:
a) knowledge of the concepts and elements of finance;
b) ability to use appropriate techniques in mathematics to represent and solve problems in finance;
c) understanding of the basic financial management issues and processes in a corporate entity.
The intended generic learning outcomes
Students who successfully complete this module will have:
a) developed a logical mathematical approach to solving problems and will be able to solve problems in finance using appropriate methods;
b) enhanced their computer skills in selection and use of electronic sources to search for and retrieve information online;
c) improved their ability to manage their time and work independently;
d) improved their key skills in numeracy, problem solving, and written communication.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

The material is covered by the lecturer's slides and the website references on them. The Actuarial Education Company's notes for Subject CT2 chapters 1 to 6, 8 and 15 to 18 provide optional reading material to the course.

Synopsis *

This module introduces and explores a range of topics relating to corporate finance which are fundamental to understanding why and how companies raise money to start a business or expand an existing one. The module covers the different ways that the money can be raised, for example from a bank or through a stocks and shares market, and the interest rate or investment return that an investor will expect to receive from a company in order to provide the money required. This is a very practical module to the extent that it will help students develop business awareness in the field of company finance. Reference will often be made to actual happenings in the financial markets in support of the material covered.

MA519 Economics 2

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

36 (36 lectures/supervised problem solving sessions)

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module students will:
a) have knowledge of the key principles of microeconomics and macroeconomics relevant for understanding models of economic behaviour;
b) be able to select and apply appropriate methods in economics;
c) be able to understand economic analysis of topics such as inflation, unemployment and macroeconomic policy;
d) understand interrelationships between different macroeconomic policies;
e) be able to analyse and evaluate equilibrium outcomes in a variety of market structures.

The intended generic learning outcomes
Students who successfully complete this module will have:
a) developed a logical mathematical approach to solving complex problems;
b) developed skills in written communication to both technical and non-technical audiences;
c) developed skills in the use of relevant information technology;
d) developed skills in time management, working with others, organisation and studying so that tasks can be planned and implemented at a professional level.

Method of Assessment

80% Examination, 20% Coursework

Pre-requisites

MA309 Business Economics

Synopsis *

This module examines recent developments and methodologies in economics and the links between the theory and practical application. Micro- and macroeconomic models of economic behaviour are developed and analysed. The syllabus includes: consumer demand, firms and supply; uncertainty and assets; macroeconomic measures; developments in growth theory; borrowing, lending and the inter-temporal budget constraint, consumption and investment theory, fiscal and monetary policy.

MA525 Survival Models II

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	
2	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	McQuire Mr P

Contact Hours

36 hours comprising lectures and group work on exercises.

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module students will be able to:
a) describe the principles of actuarial modelling;
b) describe non-parametric estimation procedures for the lifetime distribution, including censoring, the Kaplan-Meier estimate, Nelson-Aalen estimate and Cox regression model (proportional hazards model);
c) derive maximum likelihood estimators (and hence estimates) for the transition intensities in models of transfers between states with piecewise constant transition intensities;
d) describe the Binomial and Poisson models of mortality, deriving maximum likelihood estimators for the probability/force of mortality and compare with the Markov model;
e) describe how to estimate transition intensities depending on age, exactly or using the census approximation, including calculation of exposed to risk and specification of census formulae based on various age definitions;
f) describe and carry out tests for the consistency of crude estimates with a standard table or a set of graduated estimates;
g) describe the process of graduation and the advantages and disadvantages of the various methods.

The intended generic learning outcomes
Students who successfully complete this module will have further developed:
a) a logical mathematical approach to solving problems;
b) skills in oral and written communication;
c) time management and organisation skills;
d) studying.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

BSc students are recommended to purchase the relevant study notes published by the Actuarial Education Company. Arrangements will be made for students to purchase these directly from the publisher at a discount price.

Pre-requisites

MA516 Contingencies I

Restrictions

Synopsis *

Calculations in life assurance, pensions and health insurance require reliable estimates of transition intensities/survival rates. This module covers the estimation of these intensities and the graduation of these estimates so they can be used reliably by insurance companies and pension schemes. The syllabus includes the following: Principles of actuarial modelling. Distribution and density functions of the random future lifetime, the survival function and the force of hazard. Estimation procedures for lifetime distributions including censoring, Kaplan-Meier estimate, Nelson-Aalen estimate and Cox model. Statistical models of transfers between states. Maximum likelihood estimators for the transition intensities. Binomial and Poisson models of mortality. Estimation of age-dependent transition intensities. The graduation process. Testing of graduations. Measuring the exposed-to-risk.

Marks on this module can count towards examption from the professional examination CT4 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA527 Corporate Finance for Actuaries

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Bevan Mr R

Contact Hours

48 (24 lectures and 24 example classes/supervised problem solving sessions)

Learning Outcomes

The intended subject specific learning outcomes:
On successful completion of this module students will have:
• knowledge of the concepts and elements of finance;
• ability to use appropriate techniques in mathematics to represent and solve problems in finance;
• understanding of the basic financial management issues and processes in a corporate entity.
The intended generic learning outcomes
Students who successfully complete this module will have:
• developed a logical mathematical approach to solving problems and will be able to solve problems in finance using appropriate methods;
• enhanced their computer skills in selection and use of electronic sources to search for and retrieve information online;
• improved their ability to manage their time and work independently;
• improved their key skills in numeracy, problem solving, and written communication.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

The material is covered by the Actuarial Education Company's notes for Subject CT2 chapters 1 to 6, 14 to 18.

Pre-requisites

MA528 Financial Reports and their Analysis is a co-requisite module

Synopsis *

This module introduces and explores a range of topics relating to corporate finance which are fundamental to understanding why and how companies raise money to start a business or expand an existing one. The module covers the different ways that the money can be raised, for example from a bank or through a stocks and shares market, and the interest rate or investment return that an investor will expect to receive from a company in order to provide the money required. This is a very practical module to the extent that it will help students develop business awareness in the field of company finance. Reference will often be made to actual happenings in the financial markets in support of the material covered.

Marks on this module can count towards examption from the professional examination CT2 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA528 Financial Reports and their Analysis

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	70% Exam, 30% Coursework	Rogers Mr I
1	Canterbury	Spring	I	15 (7.5)	70% Exam, 30% Coursework	

Contact Hours

48 (24 lectures and 18 example classes/supervised problem solving sessions and 6 computer terminal sessions)

Learning Outcomes

The intended subject specific learning outcomes:
On successful completion of this module students will be able to:
a) Construct the main accounts normally contained within corporate annual reports.
b) Understand and interpret critically the concepts and methods of financial reporting.
c) Analyse and compare corporate results across time and between firms using horizontal and vertical analysis techniques.

The intended generic learning outcomes
Students who successfully complete this module will have:
a) Developed a logical mathematical approach to solving problems and will be able to solve problems in financial reporting and analysis using appropriate methods.
b) Enhanced their computer skills in selection and use of electronic sources to search for and retrieve information online, and to use generic commercial software and its applications to accounting.
c) Improved their ability to manage their time and work independently.
d) Improved their key skills in numeracy, problem solving, and written communication.

Method of Assessment

70% Examination, 30% Coursework

Preliminary Reading

The material is covered by the Actuarial Education Company's notes for Subject CT2, Financial accounting - Britton, Anne, Waterston, Christopher, Dawsonera 2010 and by "Interpreting Company Reports and Accounts" Geoffrey Holmes, Alan Sugden & Paul Lee 10th Edition. Prentice Hall ISBN 978-0-273-71141-4

Pre-requisites

MA527 Corporate Finance for Actuaries is a co-requisite module

Synopsis *

This module considers the construction and analysis of corporate accounts including the following: Regulatory backdrop to accounting, Accounting Principles, Basic construction of the main accounts, ie statements of comprehensive income, statements of financial position, cashflow statements and changes in equity statements, Directors' and auditors' reports, Interpretation of accounts and horizontal and vertical analysis using ratios, Limitations of accounts and ratio analysis, Group accounting structures, Peculiarities of insurance company accounts.

Marks on this module can count towards examption from the professional examination CT2 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA529 Probability and Statistics for Actuarial Science 2

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	90% Exam, 10% Coursework	Wang Dr X

Contact Hours

approximately 36 scheduled lecture hours; plus 6 workshops.

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the module, students:
a) will have a reasonable knowledge of probability theory and of the key ideas of statistical inference, in particular to enable them to study further statistics modules at levels I and H (for which this module is a pre-requisite);
b) will have a reasonable ability to use mathematical techniques to manipulate joint, marginal and conditional probability distributions, and to derive distributions of transformed random variables;
c) will have a reasonable ability to use mathematical techniques to calculate point and interval estimates of parameters and to perform tests of hypotheses;
d) will have some appreciation of the relevance of mathematical statistics to real world problems.

The intended generic learning outcomes. On successful completion of the module, students:
a) will have developed their understanding of probability and statistics;
b) will have applied a range of mathematical techniques to solve statistical problems;
c) will have developed their ability to abstract the essentials of problems and to formulate them mathematically;
d) will have improved their key skills in numeracy and problem solving;
e) will have enhanced their study skills and ability to work with relatively little supervision.

Method of Assessment

90% by a 2-hour written examination at the end of the year and 10% coursework.

Preliminary Reading

Students are provided with study notes published be the Actuarial Education Company.
I Miller & M Miller John E Freund's Mathematical Statistics with Applications, 8th ed. Pearson Education, 2012 (QA276) (R)

RV Hogg, JW McKean & AT Craig Introduction to Mathematical Statistics, 7th ed. Boston, Pearson, 2013 (QA276) (B)
HJ Larson Introduction to Probability Theory and Statistical Inference. 3rd ed. Wiley, 1982 (HA29) (B)

Synopsis *

This module is a pre-requisite for many of the other statistics modules at Stages 2, 3 and 4, but it can equally well be studied as a module in its own right, extending the ideas of probability and statistics met at Stage 1 and providing practice with the mathematical skills learned in MA321. Marks on this module can count towards exemption from the professional examination CT3 of the Institute and Faculty of Actuaries. It starts by revising the idea of a probability distribution for one or more random variables, and then looks at different methods to derive the distribution of a function of random variables. These techniques are then used to prove some of the results underpinning the hypothesis test and confidence interval calculations met at Stage 1, such as for the t-test or the F-test. With these tools to hand, the module moves on to look at how to fit models (probability distributions) to sets of data. A standard technique, known as the method of maximum likelihood, is introduced, which is then used to fit the model to the data to obtain point estimates of the model parameters and to construct hypothesis tests and confidence intervals for these parameters. Linear regression and analysis of variance models are introduced, which aim to describe the relationship between a random variable of interest and one or more covariates, for example the relationship between income and education level or gender. Outline Syllabus includes: Joint, marginal and conditional distributions of discrete and continuous random variables; Generating functions; Transformations of random variables; Poisson processes; Sampling distributions; Point and interval estimation; Properties of estimators; Maximum likelihood; Hypothesis testing; Neyman-Pearson lemma; Maximum likelihood ratio test; Simple linear regression: ANOVA.

Marks on this module can count towards exemption from the professional examination CT3 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA533 Contingencies 2

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Millett Mr J

Contact Hours

36 hours combined Lectures and Example Classes

Learning Outcomes

On successful completion of the module students will be able to:
a) Describe the calculation, using ultimate or select mortality, of net premiums and net premium reserves for increasing and decreasing benefits and annuities.
b) Describe the calculation of gross premiums and reserves of assurance and annuity contracts.
c) Describe methods which can be used to model cashflows contingent upon competing risks.
d) Describe the technique of discounted emerging costs, for use in pricing, reserving, andassessing profitability.
e) Describe the principal forms of heterogeneity within a population and the ways in which selection can occur.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

The study notes published by the Actuarial Education Company are recommended. Instructions on how to obtain these notes will be given in class.

Pre-requisites

MA516 Contingencies I

Synopsis *

Life Contingencies is concerned with the probabilities of life and death. Its practical application requires a considerable sophistication in mathematical techniques to ensure the soundness of many of the biggest financial institutions – life assurance companies and pension funds. This module introduces the actuarial mathematics which is needed for this. The aim of this module (together with MA516 – Contingencies 1) is to provide a grounding in the mathematical techniques which can be used to model and value cash flows dependent on death, survival, or other uncertain risks and cover the application of these techniques to calculate premium rates for annuities and assurances on one or more lives and the reserves that should be held for these contracts. Outline syllabus includes variable benefits and with profits contracts; gross premiums and reserves for fixed and variable benefit contracts; competing risks; pension funds; profit testing and reserves; mortality, selection and standardisation. This module together with module MA516 cover the entire syllabus of the UK Actuarial Profession's subject CT5 – Contingencies.

MA535 Portfolio Theory and Asset Pricing Models

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Nica Dr M

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the module, students will be able to:

a. Describe, perform calculations using and discuss the advantages and disadvantages of different measures of investment risk.
b. Describe, perform calculations using and discuss the assumptions of mean-variance portfolio theory and its principal results.
c. Describe utility functions, first and second order dominance, and perform calculations using commonly used utility functions to compare investment opportunities.
d. Describe, perform calculations using and discuss the properties of single and multifactor models of asset returns.
e. Describe and perform calculations using asset pricing models, discussing the principal results and assumptions and limitations of such models.
f. Discuss the various forms of the Efficient Markets Hypothesis and discuss the evidence for and against the hypothesis.
g. Demonstrate a knowledge and understanding of stochastic models of the behaviour of security prices.
h. Define and apply the main concepts of Brownian motion (or Wiener Processes).
i. Demonstrate a basic understanding of stochastic differential equations, the Ito integral, diffusion and mean-reverting processes and the Ornstein-Uhlenbeck process.
j. Discuss the key findings in behavioural finance.

The intended generic learning outcomes. On successful completion of the Module, students will have developed a logical mathematical approach to solving problems. They will have developed skills in written communication, time management and organisation and studying.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

The study notes published by the Actuarial Education Company are recommended. Instructions on how to obtain these notes will be given in class.

Elton, Edwin J; Gruber, Martin Jay, Modern portfolio theory and investment analysis, 8th Edition, Wiley, 2010.

Pre-requisites

MA529 Probability and Statistics for Actuarial Science 2 or MA629 Probability and Inference

Synopsis *

An investor needs an assortment of tools in their toolkit to weigh up risk and return in alternative investment opportunities. This module introduces various measures of investment risk and optimal investment strategies using modern portfolio theory. Pricing of assets using the classical capital asset pricing model and arbitrage pricing theory are discussed. The theory of Brownian motion is used to analyse the behaviour of the lognormal model of asset prices, which is then compared with the auto-regressive Wilkie model of economic variables and asset prices. Principles of utility theory, behavioural finance and efficient market hypothesis provide the context from an investor's perspective. Outline syllabus includes: Measures of investment risk, Mean-Variance Portfolio Theory, Capital Asset Pricing Model, Arbitrage Pricing Theory, Brownian Motion, Lognormal Model, Wilkie Model, Utility Theory and Stochastic Dominance, Efficient Market Hypothesis and Behavioural Finance.

Marks on this module can count towards exemption from the professional examination CT8 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA537 Mathematics of Financial Derivatives

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Tapadar Dr P

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the module, students will be able to:

a. Demonstrate a knowledge and understanding of the properties of option prices, valuation methods and hedging techniques.
b. Demonstrate a knowledge and understanding of models of the term structure of interest rates.
c. Demonstrate a knowledge and understanding of models for credit risk and solve problems using these models.
d. Appreciate recent developments in Financial Economics and the links between the theory of Financial Economics and their practical application

The intended generic learning outcomes. On successful completion of the Module, students will have developed a logical mathematical approach to solving problems. They will have developed skills in written communication, time management and organisation and studying.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Hull, John, Options, futures and other derivatives, 7th Edition, Prentice Hall.
Baxter, Martin; Rennie, Andrew, Financial calculus : an introduction to derivative pricing, Cambridge University Press, 1996
The study notes published by the Actuarial Education Company are recommended. Instructions on how to obtain these notes will be given in class.

Pre-requisites

MA529 Probability and Statistics for Actuarial Science 2 or MA629 Probability and Inference

Synopsis *

This module introduces the main features of basic financial derivative contracts and develops pricing techniques. Principle of no-arbitrage, or absence of risk-free arbitrage opportunities, is applied to determine prices of derivative contracts, within the framework of binomial tree and geometric Brownian motion models. The interplay between pricing and hedging strategies, along with risk management principles, are emphasized to explain the mechanisms behind derivative instruments. Models of interest rate and credit risk are also discussed in this context. Outline syllabus includes: An introduction to derivatives, binomial tree model, Black-Scholes option pricing formula, Greeks and derivative risk management, interest rate models, credit risk models.

Marks on this module can count towards exemption from the professional examination CT8 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA538 Applied Bayesian Modelling

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Leisen Dr F

Contact Hours

36

Learning Outcomes

On successful completion of this module, students will:
a. be able to derive posterior distributions when analytically tractable;
b. understand how to derive posterior summaries, such as estimates, from the posterior distribution, including the predictive distribution;
c. be able to construct Bayesian hierarchical models and implement them in a suitable software package;
d. be able to critically evaluate software output using convergence diagnostics;
e. be able to interpret and report the output for inferential purposes.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

A. Gelman, J.B. Carlin, H.S. Stern, D.B. Dunson, A. Vehtari and D.B. Rubin (2014). Bayesian Data Analysis. 3rd Edition, Chapman & Hall/CRC Texts in Statistical Science
D. Gamerman and H.F. Lopes (2006). Markov Chain Monte Carlo: Stochastic Simulation for Bayesian Inference. 2nd Edition, Taylor and Francis.

Pre-requisites

MA629 Probability and Inference

Synopsis *

The origins of Bayesian inference lie in Bayes' Theorem for density functions; the likelihood function and the prior distribution combine to provide a posterior distribution which reflects beliefs about an unknown parameter based on the data and prior beliefs. Statistical inference is determined solely by the posterior distribution. So, for example, an estimate of the parameter could be the mean value of the posterior distribution. This module will provide a full description of Bayesian analysis and cover popular models, such as the normal distribution. Initially, the flavour will be one of describing the Bayesian counterparts to well known classical procedures such as hypothesis testing and confidence intervals. Outline Syllabus includes: Bayes Theorem for density functions; Exchangeability; Choice of priors; Conjugate models; Predictive distribution; Bayes estimates; Sampling density functions; Gibbs samplers; OpenBUGS; Bayesian hierarchical models; Applications of hierarchical models; Bayesian model choice.

MA539 Financial Modelling

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	100% Coursework	Millett Mr J

Contact Hours

36 (computer classes with some lecture-based content).

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the Module, students will be able to:
a) demonstrate skills in specific actuarial software and information technology (e.g.
PROPHET)
b) understand the principles of specific actuarial mathematics techniques
c) develop simple actuarial computer models to solve actuarial problems
d) interpret and communicate the results of the models derived in b).

The intended generic learning outcomes. On successful completion of the Module, students will have developed a logical mathematical approach to solving problems. They will have developed skills in oral and written communication and developed the relevant computing skills.

Method of Assessment

• PROPHET: two coursework tests each counting 25% towards the final module mark
• Spreadsheet financial modelling: one coursework assessment counting 50% towards the final module mark

Pre-requisites

Co-requisites: MA533 Contingencies II

Synopsis *

This module is split into two parts: 1. An introduction to the practical experience of working with the financial software package, PROPHET, which is used by commercial companies worldwide for profit testing, valuation and model office work. The syllabus includes: overview of the uses and applications of PROPHET, introduction on how to use the software, setting up and performing a profit test for a product , analysing and checking the cash flow results obtained for reasonableness, using the edit facility on input files, performing sensitivity tests , creating a new product using an empty workspace by selecting the appropriate indicators and variables for that product and setting up the various input files, debugging errors in the setting up of the new product, performing a profit test for the new product and analysing the results. 2. An introduction to financial modelling techniques on spreadsheets which will focus on documenting the process of model design and communicating the model's results. The module enables students to prepare, analyse and summarise data, develop simple financial and actuarial spreadsheet models to solve financial and actuarial problems, and apply, interpret and communicate the results of such models.

Co-requisite: MA533 Contingencies II

MA549 Discrete Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	100% Exam	
1	Canterbury	Autumn	H	15 (7.5)	90% Exam, 10% Coursework	
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Woodcock Dr C

Contact Hours

38

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of the theory and practice of finite fields and their application to Latin squares, cryptography, m-sequences and cyclic codes;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: modular arithmetic, factorising polynomials, construction of finite fields, Latin squares, classical and public key ciphers including RSA, m-sequences and cyclic codes;
3 apply key aspects of discrete mathematics in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes.
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

N L Biggs, Discrete Mathematics, Oxford University Press, 2nd edition, 2002
D Welsh, Codes and Cryptography, Oxford University Press, 1988
R Hill, A First Course in Coding Theory, Oxford University Press, 1980

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA322 (Proofs and Numbers), MA323 (Matrices and Probability) or MA326 (Matrices and Computing), and MA553 (Linear Algebra)
Recommended: MA565 (Groups and Rings)
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST4001 (Algebraic Methods) or MAST4005 (Linear Mathematics)
Co-requisite: None

Synopsis *

Discrete mathematics has found new applications in the encoding of information. Online banking requires the encoding of information to protect it from eavesdroppers. Digital television signals are subject to distortion by noise, so information must be encoded in a way that allows for the correction of this noise contamination. Different methods are used to encode information in these scenarios, but they are each based on results in abstract algebra. This module will provide a self-contained introduction to this general area of mathematics.
Syllabus: Modular arithmetic, polynomials and finite fields. Applications to
• orthogonal Latin squares,
• cryptography, including introduction to classical ciphers and public key ciphers such as RSA,
• "coin-tossing over a telephone",
• linear feedback shift registers and m-sequences,
• cyclic codes including Hamming,

MA5501 Applied Statistical Modelling 1

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Kume Dr A

Contact Hours

38

Learning Outcomes

The intended generic learning outcomes.
On successfully completing the level 5 module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of R, online resources (Moodle), internet communication;.
7 communicate technical and non-technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

On successfully completing the level 6 module students will be able to:
9 manage their own learning and make use of appropriate resources;
10 understand logical arguments, identifying the assumptions made and the conclusions drawn;
11 communicate straightforward arguments and conclusions reasonably accurately and clearly;
12 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
13 solve problems relating to qualitative and quantitative information;
14 make competent use of R, online resources (Moodle), internet communication;
15 communicate technical and non-technical material competently;
16 demonstrate an increased level of skill in numeracy and computation;
17 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Chatterjee, S., and Hadi, A.S. (2012) Regression analysis by example. 5th edition. Hoboken Wiley.
Draper, N. R., and Smith, H. (1998) Applied regression analysis. 3rd edition. Wiley.
Freedman, D. (2005) Statistical models: theory and practice. Cambridge University Press.

Pre-requisites

None

Synopsis *

Constructing suitable models for data is a key part of statistics. For example, we might want to model the yield of a chemical process in terms of the temperature and pressure of the process. Even if the temperature and pressure are fixed, there will be variation in the yield which motivates the use of a statistical model which includes a random component. In this module, we study how suitable models can be constructed, how to fit them to data and how suitable conclusions can be drawn. Both theoretical and practical aspects are covered, including the use of R.

MA5502 Curves and Surfaces

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Pech Dr C

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within curves and surfaces;
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: curves and surfaces in 2d and 3d, curvatures and geodesics;
3 apply the concepts and principles in basic differential geometry in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

A. Pressley, "Elementary Differential Geometry'', Springer, London, 2010.

Pre-requisites

None

Synopsis *

The main aim of this module is to give an introduction to the basics of differential geometry, keeping in mind the recent applications in mathematical physics and the analysis of pattern recognition. Outline syllabus includes: Curves and parameterization; Curvature of curves; Surfaces in Euclidean space; The first fundamental form; Curvature of surfaces; Geodesics.

MA5503 Groups and Symmetries

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Bowman Dr C

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within basic group theory and symmetries;
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: isometries of the plane, groups, action of groups, matrix groups, symmetric groups, cyclic groups and dihedral groups;
3 apply the concepts and principles in group theory in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

M. Armstrong: Groups and Symmetry. Undergraduate Texts in Mathematics, Springer, 1988.
Peter J. Cameron, Introduction to Algebra, Second edition, Oxford University Press, 2007.

Pre-requisites

None

Synopsis *

The concept of symmetry is one of the most fruitful ideas through which mankind has tried to understand order and beauty in nature and art. This module first develops the concept of symmetry in geometry. It subsequently discusses links with the fundamental notion of a group in algebra. Outline syllabus includes: Groups from geometry; Permutations; Basic group theory; Action of groups and applications to (i) isometries of regular polyhedra; (ii) counting colouring problems; Matrix groups.

MA5504 Lagrangian and Hamiltonian Dynamics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Krusch Dr S

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within Lagrangian and Hamiltonian formulations of Newtonian mechanics, particularly the dynamics of conservative systems;
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: variational calculus, use of generalised coordinates, application of constraints, Euler-Lagrange equations, conserved quantities, Hamiltonian formulation, the Legendre Transform, interpretation of phase portraits, use of Poisson brackets;
3 apply the concepts and principles in basic Lagrangian and Hamiltonian dynamics in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Douglas Gregory, "Classical Mechanics", Cambridge University Press 2006.
Herbert Goldstein, Charles P Poole; John L Safko; "Classical mechanics", Pearson/Addison Wesley, Third edition, 2002.
Patrick Hamill, "A student's guide to Lagrangians and Hamiltonians", Cambridge University Press 2014.
Emmanuele DiBenedetto, "Classical Mechanics Theory and Mathematical Modeling", Boston, MA : Birkhäuser Boston : Imprint: Birkhäuser 2011.

Pre-requisites

None

Synopsis *

This module will present a new perspective on Newton's familiar laws of motion. First we introduce variational calculus with applications such as finding the paths of shortest distance. This will lead us to the principle of least action from which we can derive Newton's law for conservative forces. We will also learn how symmetries lead to constants of motion. We then derive Hamilton's equations and discuss their underlying structures. The formalisms we introduce in this module form the basis for all of fundamental modern physics, from electromagnetism and general relativity, to the standard model of particle physics and string theory.

MA5505 Linear Partial Differential Equations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Xenitidis Dr P

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within linear partial differential equations (PDEs);
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: separation of variables, Fourier series, the method of characteristics;
3 apply the concepts and principles in basic linear PDE methods in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

T. Myint-U, L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, Birkhäuser 2007 (online)
L. Debnath, Nonlinear Partial Differential Equations for Scientists and Engineers, 3rd edition, Birkhäuser 2012 (online)
E. Kreyszig, Advanced Engineering Mathematics, Wiley 2011

Pre-requisites

None

Synopsis *

In this module we will study linear partial differential equations, we will explore their properties and discuss the physical interpretation of certain equations and their solutions. We will learn how to solve first order equations using the method of characteristics and second order equations using the method of separation of variables.

MA5506 Macroeconomics for Financial Mathematicians

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Nica Dr M

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within macroeconomic theory;
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: basic macroeconomic concepts, understanding of macroeconomics models and macroeconomic policy;
3 apply the concepts and principles in macroeconomic theory in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Blanchard, Olivier, and David R. Johnson. Macroeconomics. 6th edition. Pearson, 2012.
N. Gregory Mankiw, Macroeconomics. 9th edition, Worth Publishers, 2015

Synopsis *

Basic macroeconomic concepts: Output and income, Unemployment, Inflation and deflation
Macroeconomic models: Aggregate demand–aggregate supply, IS–LM, Growth models
Macroeconomic policy: Monetary policy, Fiscal policy

MA5507 Mathematical Statistics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Laurence Dr A

Contact Hours

42

Learning Outcomes

8. The intended subject specific learning outcomes.
On successfully completing the level 5 module students will be able to:
8.1 demonstrate knowledge and critical understanding of the well-established principles within probability and inference;
8.2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: joint, marginal and conditional probability distributions, to derive distributions of transformed random variables, to calculate point and interval estimates of parameters and to perform tests of hypotheses;
8.3 apply the concepts and principles in probability and inference in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

9. The intended generic learning outcomes.
On successfully completing the level 5 module students will be able to:
Demonstrate an increased ability to:
9.1 manage their own learning and make use of appropriate resources;
9.2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
9.3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
9.4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
9.5 solve problems relating to qualitative and quantitative information;
9.6 make use of information technology skills such as online resources (moodle), internet communication;
9.7 communicate technical material competently;

9.8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

MILLER, I. and MILLER, M. (2014) John E. Freund's Mathematical Statistics with Applications. 8th international edition. Pearson Education, Prentice Hall, New Jersey.
LINDLEY, D.V. and SCOTT, W.F. (1995) New Cambridge Statistical Tables. 2nd edition.
HOGG, R., CRAIG, A. and McKEAN, J. (2003) Introduction to Mathematical Statistics. 6th international edition.
LARSON, H. J. (1982) Introduction to Probability Theory and Statistical Inference. 3rd edition.
SPIEGEL, M. R, SCHILLER, J. and ALU SRINIVASAN, R. (2013) Schaum's Outline of Probability and Statistics. 4th edition.
LEE, P. M. (2012) [for level 6 students] Bayesian Statistics an Introduction. 4th edition. (ebook)

Pre-requisites

None

Synopsis *

This module is a pre-requisite for many of the other statistics modules at Stages 2, 3 and 4, but it can equally well be studied as a module in its own right, extending the ideas of probability and statistics met at Stage 1 and providing practice with the mathematical skills learned in MA348 and MA349. It starts by revising the idea of a probability distribution for one or more random variables and looks at different methods to derive the distribution of a function of random variables. These techniques are then used to prove some of the results underpinning the hypothesis test and confidence interval calculations met at Stage 1, such as for the t-test or the F-test. With these tools to hand, the module moves on to look at how to fit models (probability distributions) to sets of data. A standard technique, the method of maximum likelihood, is used to fit the model to the data to obtain point estimates of the model parameters and to construct hypothesis tests and confidence intervals for these parameters. Outline Syllabus includes: Joint, marginal and conditional distributions of discrete and continuous random variables; Transformations of random variables; Sampling distributions; Point and interval estimation; Properties of estimators; Maximum likelihood; Hypothesis testing; Neyman-Pearson lemma; Maximum likelihood ratio test.

MA5509 Numerical Methods

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Deano Cabrera Dr A

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within a wide range of basic numerical methods, including iterative methods, interpolation, quadrature, finite difference approximation of initial-value problems for ordinary differential equations (ODEs);
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: root finding, interpolation, numerical quadrature, finite differences, initial-value problems for ODEs;
3 apply the concepts and principles in basic numerical approximation in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques;
4 make appropriate use of MATLAB commands to implement numerical methods.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

R. L. Burden, J. D. Faires, A. M. Burden. Numerical Analysis. 2016.
J. H. Matthews, K. D. Fink. Numerical methods using MATLAB. Pearson, 2004.
W. Gautschi. Numerical Analysis. Birkhäuser Boston, 2012 (ebook available from the Library)

Pre-requisites

None

Synopsis *

This module is an introduction to the methods, tools and ideas of numerical computation. In mathematics, one often encounters standard problems for which there are no easily obtainable explicit solutions, given by a closed formula. Examples might be the task of determining the value of a particular integral, finding the roots of a certain non-linear equation or approximating the solution of a given differential equation. Different methods are presented for solving such problems on a modern computer, together with their applicability and error analysis. A significant part of the module is devoted to programming these methods and running them in MATLAB.

MA5511 Optimisation with Financial Applications

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Kalli Dr M

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within linear and non-linear programming;
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: linear programming, non-linear programming, approximation methods;
3 apply the concepts and principles in linear and non-linear programming in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques;
4 make appropriate use of suitable software.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as appropriate software, online resources (moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Griva, I., Linear and Nonlinear Optimization, 2nd Edition, SIAM, 2008
Winston, W. L., Operations Research: Applications and Algorithms, 4th Edition, Duxbury Press, 2003

Pre-requisites

None

Synopsis *

Many problems in finance can be seen as an optimisation subject to some condition. For example, investors usually hold shares in different companies but the total number of shares that can be held is limited by the available funds. Finding the numbers of shares which maximizes the return on the investment whilst respecting the limit on funds is a problem of optimisation (of the return) subject to a condition (the total funds). In this module you learn a range of techniques to solve optimisations subject to conditions. Both theoretical and practical aspects will be covered. Outline of syllabus: Modelling linear programming applications; Graphical method; Simplex method; dual problems; duality theorem; application of duality; complementarity; sensitivity analysis; dual simplex.

MA5512 Ordinary Differential Equations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	I	15 (7.5)	80% Exam, 20% Coursework	Bearup Dr D

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within ordinary partial differential equations (ODEs);
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: phase portraits, stability of fixed points, the Frobenius method, autonomous linear systems of ODEs;
3 apply the concepts and principles in basic ODE methods in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

E. Kreyszig, Advanced Engineering Mathematics (10th edition), John Wiley, 2011
Robert L. Borrelli, Courtney S. Coleman, Differential Equations: A Modeling Perspective, 2nd Edition (ISBN: 978-0-471-43332-3), 2004.

Pre-requisites

None

Synopsis *

This module introduces the basic ideas to solve certain ordinary differential equations, like first order scalar equations, second order linear equations and systems of linear equations. It mainly considers their qualitative and analytical aspects.
Outline syllabus includes: First-order scalar ODEs; Second-order scalar linear ODEs; Existence and Uniqueness of Solutions; Autonomous systems of two linear first-order ODEs.

MA5513 Real Analysis 2

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Wood Dr I

Contact Hours

42

Learning Outcomes

On successfully completing the module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within mathematical analysis;
2 demonstrate the capability to use a range of established techniques and a reasonable level of skill in calculation and manipulation of the material to solve problems in the following areas: uniform continuity of functions, sequences of functions, uniform convergences, series, power series, Riemann integration, functions of several variables, differentiation of functions of several variables;
3 apply the concepts and principles in mathematical analysis in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
Demonstrate an increased ability to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% exam, 20% coursework

Preliminary Reading

Recommended reading:
B. S. Thomson, A. M. Bruckner, and J. B. Bruckner, Elementary Real Analysis (2nd Edition), 2008.
W. Rudin, Principles of mathematical analysis (3rd Edition), International Series in Pure and Applied Mathematics. McGraw-Hill Book Co., New York-Auckland-Düsseldorf, 1976.
Additional reading:
T.M Apostol, Mathematical analysis (2nd edition).. Addison-Wesley Publishing Co., Reading, Mass.-London-Don Mills, Ont., 1974.
K.G. Binmore, Mathematical analysis. A straightforward approach (2nd edition). Cambridge University Press, Cambridge-New York, 1982.

Synopsis *

This module builds on the Stage 1 Real Analysis 1 module. You will extend your knowledge of functions of one real variable, look at series, and study functions of several real variables and their derivatives. Outline syllabus includes: Continuity and uniform continuity of functions of one variable; Sequences of functions; Series; The Riemann integral; Functions of several variables; Differentiation of functions of several variables; Extrema; Inverse function and Implicit function theorems.

MA561 Introduction to Lie Groups and Algebras

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
3	Canterbury	Autumn	M	15 (7.5)	70% Exam, 30% Coursework	

Contact Hours

30 hours

Learning Outcomes

On successful completion of this module, H-level students will
(i) be aware of the range of algebraic, geometric and analytic issues that the study of Lie groups and Lie algebras entail, be able to reason confidently from algebraic definitions such as ideals, bilinear forms, representations and root spaces, be able to calculate confidently with basic constructions such as vector fields, Lie brackets, exponentials, and adjoint representations, and be able to determine the Lie algebra of a Lie group and in particular to understand its nature as a tangent space to the group;
(ii) have developed intuition for the structure of the main examples of Lie groups and Lie algebras that arise in applications, including nonlinear Lie group actions;
(iii) developed awareness of non-commutative phenomena;
(iv) be aware of topics which are an important tool of research in many areas of Mathematics, Physics and Chemistry.
(v) have understood and be able to discuss the role played by Lie groups and algebras in at least one application area in detail;
(vi) have used the computer algebra package MAPLE to perform calculations in specified Lie groups and Lie algebras.

On successful completion of this module, M-level students will also:
(vii) have a systematic understanding of the algebraic, geometric and analytic issues that the study of Lie algebras and Lie groups entail;
(viii) have developed a comprehensive understanding of techniques for the application of Lie algebra.

Method of Assessment

70% Examination, 30% Coursework

Preliminary Reading

ML Curtis, Matrix Groups. (Springer Verlag, Second edition, 1984) (B)
R Gilmore, Lie groups, Lie algebras, and some of their applications. (New York, Wiley, 1974) (R)
N Jacobson, Lie algebras. (New York, Interscience Publishers, 1962) (B)
AW Knapp, Lie groups beyond an introduction. (Birkhäuser, Second edition, 2002) (B)
K Tapp, Matrix groups for undergraduates. (Student Mathematical Library 29, American Mathematical Society, 2005) (R)

A Fässler & E Stiefel, Group Theoretical Methods and their applications. (Boston, Birkhäuser, 1992) (R)

Synopsis *

Lie groups and their associated Lie algebras are studied by both pure and applied mathematicians and by physicists; this is a topic renowned for both its mathematical beauty and its immense utility. Lie groups include translation, rotation and scaling groups as well as unitary, symplectic and special linear matrix groups. We will study in detail the lower dimensional groups that arise in many applications, and more general theory such as the structure of their associated Lie algebras. Special topics include a look at the lowest dimensional exceptional Lie group G2, and Lie group actions and their invariants.

MA566 Number Theory

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	I	15 (7.5)	80% Exam, 20% Coursework	Pech Dr C

Contact Hours

Up to 48

Learning Outcomes

The intended subject specific learning outcomes
Students who successfully complete this module will:
a) understand and be able to cite a representative selection of the definitions and theorems of basic Number Theory;
b) execute simple proofs and deductions using the concepts of Number Theory and express their reasoning with reasonable clarity;
c) perform simple calculations and work through basic examples involving number theoretic concepts;
d) appreciate the role of Number Theory in modern cryptography.

The intended generic learning outcomes
Students who successfully complete this module will have further developed:
a) a logical, mathematical approach to solving problems;
b) their ability to communicate solutions, simple proofs and calculations;
c) their numeracy and computational skills;
d) their ability to plan and carry out effective ways of studying;
e) their ability to read and comprehend mathematical ideas.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

D.M. Burton, Elementary Number Theory, McGraw-Hill, 2010.
G.A. Jones and J.M. Jones, Elementary Number Theory, Springer, 1998.
W. Stein, Elementary Number Theory: Primes, Congruences, and Secrets, Undergraduate Texts in Mathematics, Springer, 2009.

Pre-requisites

None

Synopsis *

The security of our phone calls, bank transfers, etc. all rely on one area of Mathematics: Number Theory. This module is an elementary introduction to this wide area and focuses on solving Diophantine equations. In particular, we discuss (without proof) Fermat's Last Theorem, arguably one of the most spectacular mathematical achievements of the twentieth century.
Outline syllabus includes: Modular Arithmetic; Prime Numbers; Introduction to Cryptography; Quadratic Residues; Diophantine Equations.

MA567		Topology				
Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Sibilla Dr N

Contact Hours

38

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of this module, students will be able to:
1 understand the basic concepts of topology;
2 apply notions from point-set topology to problems in geometry;
3 appreciate non-Euclidean geometric concepts;
4 develop awareness of relations to other mathematical areas such as Calculus, Metric Spaces and Functional Analysis.

The intended generic learning outcomes. On successful completion of the module, the students will have:
1 an enhanced ability to reason and deduce confidently from given definitions and constructions;
2 enhanced knowledge of associated abstract geometric concepts with applications;
3 matured in their problem formulating and solving skills;
4 consolidated their grasp of a wide variety of mathematical skills and methods.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

J.G. Hocking and G. Young: Topology, Dover Publications, 1988
J.R. Munkres: Topology, a first course, Prentice-Hall, 1975
C. Adams and A. Franzosa: Introduction to Topology, pure and applied, Pearson Prentice-Hall, 2008

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA552 (Analysis)
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST5013 (Real Analysis 2)
Co-requisite: None

Synopsis *

This module is an introduction to point-set topology, a topic that is relevant to many other areas of mathematics. In it, we will be looking at the concept of topological spaces and related constructions. In an Euclidean space, an "open set" is defined as a (possibly infinite) union of open "epsilon-balls". A topological space generalises the notion of "open set" axiomatically, leading to some interesting and sometimes surprising geometric consequences. For example, we will encounter spaces where every sequence of points converges to every point in the space, see why for topologists a doughnut is the same as a coffee cup, and have a look at famous objects such as the Moebius strip or the Klein bottle.

MA568 Orthogonal Polynomials and Special Functions

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Soares Loureiro Dr A

Contact Hours

38

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module, students will be able to:
a) understand the basic concepts of orthogonal polynomials and special functions;
b) have sound knowledge of inner products in L2-spaces as well as the skills to apply this knowledge to problems in differential and difference equations;
c) understand how to apply the theory of analytical functions, differential and difference equations and asymptotic methods.

The intended generic learning outcomes
On successful completion of the module, the students will have:
a) an enhanced ability to reason and deduce confidently from given definitions and constructions;
b) enhanced knowledge of special functions and their geometric, analytical and asymptotic properties;
c) matured in their problem formulating and solving skills;
d) consolidated their grasp of a wide variety of mathematical skills and methods.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

The module does not follow a specific text. However, the following texts cover the material.
R. Askey, Orthogonal Polynomials and Special Functions, Society for Industrial and Applied Mathematics, Philadelphia, PA, 1975
R. Beals and R. Wong, Special Functions – A Graduate Text, Cambridge University Press, Cambridge, 2010
T.S. Chihara, An Introduction to Orthogonal Polynomials, Dover Publ., Mineola, N.Y., 2011
M. Ismail, Classical and Quantum Orthogonal Polynomials in One Variable, Cambridge University Press, Cambridge, 2005
F.W.J. Olver, D.W. Lozier, C.W. Clark,R.F. Boisvert, Digital Library of Mathematical Functions, National Institute of Standards and Technology, Gaithersburg, U.S.A., 2010 (http://dlmf.nist.gov)
I.N. Sneddon, Special Functions of Mathematical Physics and Chemistry, 3rd Edition, Longman, London, 1980
G. Szego, Orthogonal Polynomials, 4th Ed., American Mathematical Society, Providence, RI, 1975

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA321 (Calculus and Mathematical Modelling), MA322 (Proofs and Numbers), MA323 (Matrices and Probability), MA552 (Analysis), MA588 (Mathematical Techniques and Differential Equations).

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST4004 (Linear Algebra); MAST4010 (Real Analysis 1); MAST5013 (Real Analysis 2); MAST5012 (Ordinary differential equations).

Synopsis *

This module provides an introduction to the study of orthogonal polynomials and special functions. They are essentially useful mathematical functions with remarkable properties and applications in mathematical physics and other branches of mathematics. Closely related to many branches of analysis, orthogonal polynomials and special functions are related to important problems in approximation theory of functions, the theory of differential, difference and integral equations, whilst having important applications to recent problems in quantum mechanics, mathematical statistics, combinatorics and number theory. The emphasis will be on developing an understanding of the structural, analytical and geometrical properties of orthogonal polynomials and special functions. The module will utilise physical, combinatorial and number theory problems to illustrate the theory and give an insight into a plank of applications, whilst including some recent developments in this field. The development will bring aspects of mathematics as well as computation through the use of MAPLE. The topics covered will include: The hypergeometric functions, the parabolic cylinder functions, the confluent hypergeometric functions (Kummer and Whittaker) explored from their series expansions, analytical and geometrical properties, functional and differential equations; sequences of orthogonal polynomials and their weight functions; study of the classical polynomials and their applications as well as other hypergeometric type polynomials.

MA569 Starting Research in the Mathematical Sciences

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn and Spring	H	15 (7.5)	70% Project, 30% Coursework	

Contact Hours

6-8 hours supervised workshops; arranged supervision time with project supervisor

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of the module students will have:
a) gained the ability to systematically find scientific resources and to evaluate the materials found in terms of quality and reliability;
b) developed skills in critical reading and editing of mathematical or statistical documents;
c) appreciated an area of mathematics or statistics in more depth than in taught courses by carrying out independent investigation;
d) enhanced their capacity to communicate mathematical ideas;
e) acquired the ability to report the results of their studies concisely and accurately.

The intended generic learning outcomes
On successful completion of the module, students will have:
a) improved communication skills;
b) enhanced intellectual independence;
c) developed relevant computing skills, including use of appropriate document preparation and word-processing packages;
d) improved problem solving skills;
e) acquired an ability to select material from a range of relevant learning and reference resources;
f) developed their ability for independent learning and time management.

Method of Assessment

70% Project, 30% Coursework

Pre-requisites

MA321 (Calculus and Mathematical Modelling), MA322 (Proofs and Numbers), MA323 (Matrices and Probability), MA324 (Exploring Mathematics), MA306 (Statistics); Stage 2 - MA552 (Analysis), MA553 (Linear Algebra), MA629 (Probability and Inference)

Synopsis *

This module has two components: (i) A series of workshops on key skills: The interactive workshops will cover general research methods possibly including library & information systems, mathematical reading, referencing conventions, coherent mathematical writing, typesetting using LaTeX and presentation skills. (ii) Independent project work: A list of possible topics will be offered. The description of each project will include a reference to a single journal article. The student will carry out independent study on one topic based on the journal article listed.

MA572 Complex Analysis

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	100% Exam	
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Autumn	H	15 (7.5)	90% Exam, 10% Coursework	

Contact Hours

48 (approx.. 36 lectures and 12 example classes).

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module students will:
a) Have a reasonable ability to perform basic computational skills: calculations with Cartesian and polar form of complex numbers, modulus and argument; roots of unity; partial fractions and the general binomial theorem; calculations with exponential, trigonometric and hyperbolic functions, complex logarithm and complex exponents, and hyperbolic functions.
b) Have a reasonable knowledge, and understand the place in the theory and the proofs: of the Cauchy Fundamental Theorem, Cauchy Integral Formulae with and without winding numbers, the Deformation Theorem, Existence and formulae for Taylor and Laurent series, differentiability of power series, Cauchy Residue Theorem, the Cauchy-Riemann equations, a proof of the Fundamental Theorem of Algebra..
c) Gain experience and solve problems using more advanced analytic skills such as: computation of Taylor and Laurent series; radius of convergence of power series; calculation of residues and types of singularity; evaluation of integrals using residues, possibly including the use of Riemann surfaces; homotopy of paths to ease calculations of path integrals; use of winding numbers of paths; evaluation of limits and differentiability of a complex function; conjugate harmonic functions.

The intended generic learning outcomes
Students who successfully complete this module will have further developed:
a) a logical mathematical approach to solving problems;
b) an ability to solve problems relevant to applications in engineering and physics;
c) the basic skills for postgraduate studies in topology, engineering mathematics and applied analysis.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

M.R. Spiegel Complex Variables, McGraw-Hill, 1964
H.A. Priestley Introduction to Complex Analysis, Oxford University Press, 2003
J.H. Mathews & R.W Howell Complex Analysis for Mathematics and Engineering, Jones and Bartlett 5th ed., 2006
I Stewart & D Tall, Complex Analysis, Cambridge, 2004

Pre-requisites

MA552 (for undergraduate courses only)

Synopsis *

This module is concerned with complex functions, that is functions which are both defined for and assume complex values. Their theory follows a quite different development from that of real functions, is remarkable in its directness and elegance, and leads to many useful applications.Topics covered will include: Complex numbers. Domains and simple connectivity. Cauchy-Riemann equations. Integration and Cauchy's theorem. Singularities and residues. Applications.

MA574 Polynomials in Several Variables

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	70% Exam, 30% Coursework	Shank Dr RJ
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Shank Dr RJ
1	Canterbury	Spring	H	15 (7.5)	70% Exam, 30% Coursework	

Contact Hours

36

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of polynomials in several variables;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: solution sets for systems of polynomial equations and the corresponding ideals in the ring of polynomials;
3 apply key aspects of polynomial in several variables in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the selection and application of computer calculation of Gröbner bases.

The intended generic learning outcomes.
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Adams, Loustaunau, An introduction to Gröbner bases, AMS, 1994
Cox, Little, O'Shea, Ideals, Varieties and Algorithms, Springer, Undergraduate Texts in Mathematics, 1991
Hibi, Gröbner bases: Statistics and Software Systems, Springer, 2013

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA322 (Proofs and Numbers), MA323 (Matrices and Probability) or MA326 (Matrices and Computing), and MA553 (Linear Algebra)
Recommended: MA324 (Exploring Mathematics), MA565 (Groups and Rings)
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MA343 (Algebraic Methods), MA5503 (Groups and Symmetries)
Recommended: MA5514 (Rings and Fields)
Co-requisite: None

Synopsis *

This module provides a rigorous foundation for the solution of systems of polynomial equations in many variables. In the 1890s, David Hilbert proved four ground-breaking theorems that prepared the way for Emmy Nöther's famous foundational work in the 1920s on ring theory and ideals in abstract algebra. This module will echo that historical progress, developing Hilbert's theorems and the essential canon of ring theory in the context of polynomial rings. It will take a modern perspective on the subject, using the Gröbner bases developed in the 1960s together with ideas of computer algebra pioneered in the 1980s. The syllabus will include
• Multivariate polynomials, monomial orders, division algorithm, Gröbner bases;
• Hilbert's Nullstellensatz and its meaning and consequences for solving polynomials in several variables;
• Elimination theory and applications;
• Linear equations over systems of polynomials, syzygies.

MA576 Groups and Representations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Bowman Dr C
1	Canterbury	Spring	H	15 (7.5)	90% Exam, 10% Coursework	Bowman Dr C

Contact Hours

40 hours of lectures and classes

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of the theory and practice of groups (with examples including permutation groups and matrix groups, and the combinatorics of the symmetric group), of linear algebra, and of representations and characters of groups.
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: calculations within permutation groups and matrix groups; computations of the character tables of small groups; derivation of structural information about a group from its character table; formulation and proof of simple statements about groups and representations in precise abstract algebraic language; breaking up representations into smaller simpler objects.
3 apply key aspects of group theory and representation theory in well-defined contexts, showing judgement in the selection and application of tools and techniques.

On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources.
2 understand logical arguments, identifying the assumptions made and the conclusions drawn
3 communicate straightforward arguments and conclusions reasonably accurately and clearly
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working
5 solve problems relating to qualitative and quantitative information
6 make competent use of information technology skills such as online resources (moodle), internet communication.
7 communicate technical material competently
8 demonstrate an increased level of skill in numeracy and computation
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

We will not follow a single text, and the lecture notes will cover the entire syllabus. Nevertheless
G.D. James and M. Liebeck, Representations and characters of groups, CUP (2001)
J.P. Serre, Linear representations of finite groups, Springer GTM (1977)
J.L. Alperin and R.B. Bell, Groups and Representations, Springer GTM (1995)
contain a large amount of the material.

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA553 (Linear Algebra), MA325 (From Geometry to Algebra), MA565 (Groups and Rings).
Co-requisite: None

For delivery to students completing Stage 1 from September 2016:
Pre-requisite: MAST4004 (Linear Algebra), MAST5003 (Groups and Symmetries)
Co-requisite: None

Synopsis *

Groups arise naturally in many areas of mathematics as well as in chemistry and physics. A concrete way to approach groups is by representing them as a group of matrices, in which explicit computations are easy. This approach has been very fruitful in developing our understanding of groups over the last century. It also helps students to understand aspects of their mathematical education in a broader context, in particular concepts from earlier modules (From Geometry to Algebra/Groups and Symmetries and Linear Algebra) have been amalgamated into more general and powerful tools.

This module will provide a rigorous introduction to the main ideas and notions of groups and representations. It will also have a strong computational strand: a large part of the module will be devoted to explicit computations of representations and character tables (a table of complex numbers associated to any finite group).

MA577 Elements of Abstract Analysis

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours
48

Learning Outcomes
The Intended Subject Specific Learning Outcomes. On successful completion of the module students will:
(a) be able to work with fundamental concepts in analysis and metric spaces including, Cauchy sequences, compactness, completeness, inner-product spaces, and complete orthonormal systems;
(b) have a grasp of formal definitions and rigorous proofs in analysis;
(c) have gained an appreciation of a wider context in which previously encountered concepts from analysis can be used;
(d) be able to apply abstract ideas to concrete problems in analysis;
(e) be aware of applications of basic techniques and theorems of metric spaces and analysis in other areas of mathematics, e.g., approximation theory, and the theory of ordinary differential equations.

The Intended Generic Learning Outcomes. We expect students successfully completing the module to have
(i) an enhanced ability to correctly formulate abstract problems and solve them efficiently;
(ii) enhanced skills in understanding and communicating mathematical results and conclusions;
(iii) furthered a holistic view of mathematics as a problem solving and intellectually stimulating discipline;
(iv) an appreciation of the power of abstract reasoning and formal proofs in mathematics and its applications

On completion of the module students will have:
• matured in their problem formulating and solving skills;
• enhanced their ability to apply abstract methods and theorems from analysis in a wide context.

Method of Assessment
80% Examination, 20% Coursework

Preliminary Reading
- E Kreyszig, Introductory Functional Analysis with Applications. (John Wiley, 1978) (B)
- W Rudin, Principles of Mathematical Analysis. (International Series in Pure and Applied Mathematics, McGraw-Hill, 1976) (B)
- N Young, An Introduction to Hilbert space. (Cambridge University Press, 1998) (R)
- JR Giles, Introduction to the Analysis of Metric Spaces. (Australian Mathematical Society Lecture Series, Cambridge, 1987) (R)
- K Saxe, Beginning Functional Analysis. (Springer, 2002) (B)

Synopsis *
In this module we build on the key analytical concepts of sequences, series, limits,and continuity developed in any first course on Real Analysis, and place them in the more general context of metric spaces. In the first part of the course fundamental notions of metric spaces, such as compactness and completeness, are discussed. Metric space theory underpins much of modern anaylisis and its applications. In the second part of the course we use techniques and theorems from metric spaces to discuss elements of Hilbert space theory. The course emphasizes formal definitions and proofs, and aims to enable you to place your previous knowledge of anaylsis in a much wider context.

The syllabus will be taken from the following topics:
(1) Metric space theory.
• Definitions and examples of metric spaces, normed spaces, inner-product spaces.
• Balls, boundedness, open and closed sets.
• Convergence, Cauchy sequences, completeness, and equivalence of metrics.
• Completion of a metric space, uniform convergence, and exchanging limits.
• Incompleteness of the space of Riemann-integrable functions under Lp-norms, and an informal discussion of its completion, i.e., Lp-spaces. The space of continuous functions and supremum norm.
• Limit points, closure, boundary, separability, density.
• Banach contraction mapping theorem; applications to ODE theory (Picard's theorem), and/or integral equations.
• Continuity in metric spaces, uniform continuity, and continuity of linear mappings.
• Compactness, sequential compactness, Heine-Borel, Non-compactness of balls in infinite dimensional normed spaces.
• The spaces of continuous functions C(X) on a compact metric space X, and the Weierstrass approximation theorem.

(2) Basic Hilbert space theory.
• Definitions and examples of inner-product spaces, Hilbert spaces, Cauchy-Schwarz inequality, parallelogram identity, l2 and L2([a,b]).
• Orthogonal complements and orthogonal projections.
• Orthonormal sets and Gram-Schmidt orthogonalisation.
• Examples of orthogonal polynomials, e.g., Legendre polynomials and/or Chebyshev polynomials.
• Complete orthonormal systems, Bessel's inequality, Parseval's theorem, and the Riesz-Fisher theorem. Trigonometric series and L2 convergence.

MA578 Dissertation for MMath Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn and Spring	M	30 (15)	70% Project, 30% Coursework	Wood Dr I

Contact Hours

4 hours supervised workshops; arranged supervision time with project supervisor (approx.. 6 hours)

Learning Outcomes

The intended subject specific learning outcomes
Upon successful completion of the module and depending on the particular topic (as approved by the module convener), students will:
a) be aware of the breadth, depth and wider relevance of an advanced mathematical topic of current interest;
b) have improved their writing and oral communication skills gained in Starting Research in the Mathematical Sciences (MA569) module;
c) have demonstrated the ability to comprehend problems, abstract the essentials of problems and formulate them mathematically to facilitate their analysis and solution;
d) be able to present mathematical arguments and to draw conclusions from mathematical calculation and/or computer output;
e) have a reasonable ability to apply mathematical concepts and statistical techniques in a particular context.

The intended generic learning outcomes.
On successful completion of the module, students will have:
a) improved communication skills;
b) enhanced intellectual independence;
c) improved information retrieval skills including appropriate selection of materials and their critical evaluation;
d) improved problem solving skills;
e) demonstrated computational skills and some basic reasoning skills;
f) developed their ability for independent learning and time management.

Method of Assessment

70% Project, 30% Coursework

Pre-requisites

Stage 1: MA321 Calculus and Mathematical Modelling, MA322 Proofs and Numbers, MA323 Matrices and Probability, MA324 Exploring Mathematics; Stage 2: MA552 Analysis, MA553 Linear Algebra; Stage 3: MA569 Starting Research in the Mathematical Sciences

Synopsis *

The module offers students the opportunity to work independently, under limited supervision, on an area of mathematics of their choice. There is no specific mathematical syllabus for this module. The topic of the dissertation will depend on the mutual interests of the student and the student's chosen supervisor. The coursework will consist of writing a dissertation plan, an oral presentation of material from the dissertation to examiners and an interview of the student by the examiners. There will be four workshops on key skills relevant to dissertation planning and oral presentation.

MA5801 Industrial Placement Experience

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn and Spring	I	90 (45)	100% Coursework with Pass/Fail Elements	

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate that they can perform effectively in a work based environment;
2 identify and discuss examples of the links between academic theory and practical application;
3 demonstrate an enhanced capacity for independent thought and work;
4 reflect on on-going personal and professional development.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate a wide range of generic/transferable skills, including communication and the ability to work in a team
2 identify actions required for their career development.

Method of Assessment

This module is assessed by three separate components.
• Performance and demonstrated abilities on the job, evaluated by the placement supervisor
• Half Yearly and End of Year reviews of personal and professional development together with an End of Year Development Plan
• On-line Blogs – Weekly for 1st month and every two months thereafter
Each of the 3 components is assessed separately on a pass / fail basis.

Pre-requisites

Co-requisite MAST5802 Industrial Placement (Report and Presentation)

Synopsis *

Students spend a year (minimum 900 hours) doing paid work in an organisation outside the University, usually in an industrial or commercial environment, applying and enhancing the skills and techniques they have developed and studied in the earlier stages of their degree programme.

The work they do is entirely under the direction of their industrial supervisor, but support is provided by the SMSAS Placement Officer or a member of the academic team. This support includes ensuring that the work they are being expected to do is such that they can meet the learning outcomes of the module.

Participation in this module is dependent on students obtaining an appropriate placement, for which support and guidance is provided through the School in the year leading up to the placement. It is also dependent on students progressing from Stage 2 of their studies.

Students who do not obtain a placement will be required to transfer to the appropriate programme without a Year in Industry.

MA5802 Industrial Placement (Report and Presentation)

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn and Spring	I	30 (15)	100% Coursework	

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate understanding of how their employer's business fits into the wider economic context, and how their role and activities fit into this;
2 identify and discuss example of the links between academic theory and practical application;
3 demonstrate an enhanced capacity for independent thought and work;
4 demonstrate research, presentation and report-writing skills;
5 reflect on on-going personal and professional development.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate a wide range of generic/transferable skills, including: presentation and communication
2 identify the actions required for their career development.

Method of Assessment

This module is assessed by the following The module mark is based on:
• a Placement Report   – 50% of total module mark
• production of an industrial placement poster, and delivering a short presentation based on the poster – 50 % of total module mark.

Pre-requisites

Co-requisite: MAST5801 (Industrial Placement Experience)

Synopsis *

Students spend a year (minimum 900 hours) doing paid work in an organisation outside the University, usually in an industrial or commercial environment, applying and enhancing the skills and techniques they have developed and studied in the earlier stages of their degree programme. Employer evaluation, personal and professional reviews and on-line blogs are assessed under MAST5801 (Industrial Placement Experience) which is a co-requisite of this module. The assessment of this module draws on the experience gained in MAST5801 and is assessed through a Placement Report and Presentation.

The placement work they do is entirely under the direction of their industrial supervisor, but support is provided by the SMSAS Placement Officer or a member of the academic team. This support includes ensuring that the work they are being expected to do is such that they can meet the learning outcomes of this module.

Participation in the placement year, and hence in this module, is dependent on students obtaining an appropriate placement, for which support and guidance is provided through the School in the year leading up to the placement. It is also dependent on students progressing satisfactorily from Stage 2 of their studies.

Students who do not obtain a placement or who fail module MAST5801 (Industrial Placement Experience) will be required to transfer to the appropriate programme without a Year in Industry and any marks obtained on this module will not contribute to their final degree classification.

MA587 Numerical Solution of Differential Equations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Deano Cabrera Dr A
1	Canterbury	Autumn	H	15 (7.5)	90% Exam, 10% Coursework	Deano Cabrera Dr A
1	Canterbury	Spring	H	15 (7.5)	90% Exam, 10% Coursework	

Contact Hours

42

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate systematic understanding of key aspects of finite difference methods for approximating solutions of ordinary differential equations (ODEs) and partial differential equations (PDEs);
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: multistep methods, approximation of boundary value problems for ODEs, discretization of PDEs, error and stability analysis, elementary numerical linear algebra;
3 apply key aspects of finite difference methods in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the selection and application of Matlab commands to implement numerical methods.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Burden, R.L., and Faires, J.D., and Burden, A. M., Numerical Analysis, 10th edition, Cengage Learning, 2016
Iserles, A first course in the numerical analysis of differential equations, 2nd edition, Cambridge University Press, 2009
Morton, K. W. and Mayers, D.F., Numerical solution of partial differential equations: an introduction, Cambridge University Press, 2011

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA552 (Analysis), MA553 (Linear Algebra)
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST5005 (Linear Partial Differential Equations), MAST5009 (Numerical Methods), MAST5012 (Ordinary differential equations)
Co-requisite: None

Synopsis *

Most differential equations which arise from physical systems cannot be solved explicitly in closed form, and thus numerical solutions are an invaluable way to obtain information about the underlying physical system. The first half of the module is concerned with ordinary differential equations. Several different numerical methods are introduced and error growth is studied. Both initial value and boundary value problems are investigated. The second half of the module deals with the numerical solution of partial differential equations. The syllabus includes: initial value problems for ordinary differential equations; Taylor methods; Runge-Kutta methods; multistep methods; error bounds and stability; boundary value problems for ordinary differential equations; finite difference schemes; difference schemes for partial differential equations; iterative methods; stability analysis.

MA591 Nonlinear Systems and Mathematical Biology

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

36 lectures, 12 classes

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module students will:
a) appreciate a variety of different nonlinear phenomena;
b) be able to derive qualitative results for nonlinear ordinary/ partial differential and difference equations;
c) know how to analyse and interpret basic mathematical models of biological systems;
d) have an understanding of the concepts of bifurcation, chaos, and equilibrium stability in nonlinear dynamical systems;
e) be able to synthesize analytical, geometrical and numerical techniques, as well as computation with MAPLE, in the description of real world phenomena from biology.

The intended generic learning outcomes
Students who successfully complete this module will have developed:
a) a qualitative approach to the analysis of problems in mathematical biology through the use of nonlinear dynamical systems;
b) their ability to communicate the results of calculations and the solutions of problems;
c) their numeracy and computational skills;
d) their ability to plan and carry out effective ways of studying;
e) their key skills in numeracy, problem solving and computing.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

JD Murray - Mathematical Biology. (2nd ed. Springer-Verlag 1993) (E)
and Mathematical Biology, Volumes I & II (3rd ed., Springer-Verlag 2002-3) (R)
DW Jordan and P Smith Nonlinear Ordinary Differential Equations (3rd Ed, Oxford 1999). ®
D Kaplan and L Glass Understanding Nonlinear Dynamics. (Springer 1995)
P Glendinning Stability, instability and chaos (Cambridge, 1994)

Pre-requisites

MA552 and MA553; MA590 are recommended

Synopsis *

This module provides an introduction to the study of properties of solutions of nonlinear ordinary differential equations, difference equations and their application to problems in Biology. The emphasis will be on developing an understanding of nonlinear systems and using practical analytical techniques to analyse them. The module will utilise biological models to illustrate the theory and give an insight into how Mathematics can be of practical use in the study of phenomena which are observed in the real world. The module will cover topics in the following areas: Continuous population models for single species; Discrete population models; Phase plane analysis; Continuous models for Interacting Populations (including predator-prey, competition and mutualism models); Stability, instability and limit cycles; Reaction kinetics; Reaction-diffusion models.

MA594 Advanced Regression Modelling with R

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

36

Learning Outcomes

On successful completion of this module students will:
a) be proficient in the use of the statistical package R;
b) be able to select suitable regression methods to analyse data in a sensible way and interpret the results appropriately;
c) be able to provide clear and competent reports on statistical analyses;
d) have a systematic understanding of linear and generalized linear modelling, and be able to apply these techniques critically to real world data using R;
e) be able to interpret the results of analyses, and communicate these clearly and concisely to other statisticians and to non-statisticians.

The intended generic learning outcomes
On successful completion of this module students will:
a) be able to plan and implement the analysis of unfamiliar material in a professional way;
b) be able to use information technology effectively for advanced data analysis;
c) have enhanced their computational skills in statistical modelling;
d) have developed a logical, mathematical approach to their work;
e) be able to appropriately manipulate data for regression analysis;
f) appreciate the need for techniques used to be appropriate to the type of data available.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

Crawley, M. .J. (2009). The R Book, Wiley.
Draper, N. R. and Smith, H. (1998), Applied Regression Analysis, 3rd ed. Wiley.
Faraway, J. J. (2004). Linear Models with R, Chapman and Hall.
Faraway, J. J. (2006). Extending the Linear Model with R, Chapman and Hall.
McCullagh, P. and Nelder, J. A. (1989). Generalized Linear Models, 2nd ed, Chapman and Hall.

Pre-requisites

Pre-requisite modules: MA629 Probability and Inference, MA632 Regression Models

Synopsis *

R Package: This part will include a general introduction to the package and its components covering: linear models in R, writing your own functions in R, generalized linear models in R.
Further linear regression: Model selection, collinearity, outliers and influential observations, polynomial regression.
Generalized Linear Model: Exponential family; Discrete data distributions: definition, estimation and testing; GLMs: estimation, model selection and model checking; Examples of GLMs: logistic regression and Poisson regression; Overdispersion;

MA595 Graphs and Combinatorics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48 lectures and example classes

Learning Outcomes

On successful completion of this module, students will:
1 have gained knowledge of the fundamental concepts and results in graph theory and combinatorics;
2 be able to describe and solve a mathematical problem using graphs and combinatorial arguments;
3 have gained further knowledge of discrete structures in mathematics;
4 have gained a working knowledge of various fundamental graph algorithms;
5 have an ability to understand constructive proofs and to be able to use them to design algorithms.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

P. Cameron, Combinatorics, Topics, Techniques Algorithms, Cambridge Press, (1994)
L. Lovasz, J. Pelikan, and K. Vesztergombi, Discrete Mathematics: Elementary and Beyond. Springer-Verlag, (2003).
D. B. West, Introduction to Graph Theory, Prentice Hall, (1996).
R.J. Wilson, Introduction to Graph Theory, Fourth edition. Longman, Harlow, (1996).

Pre-requisites

None

Synopsis *

Combinatorics is a field in mathematics that studies discrete, usually finite, structures, such as graphs. It not only plays an important role in numerous parts of mathematics, but also has real world applications. In particular, it underpins a variety of computational processes used in digital technologies and the design of computing hardware.
Among other things, this module provides an introduction to graph theory. Graphs are discrete objects consisting of vertices that are connected by edges. We will discuss a variety of concepts and results in graph theory, and some fundamental graph algorithms. Topics may include, but are not restricted to: trees, shortest paths problems, walks on graphs, graph colourings and embeddings, flows and matchings, and matrices and graphs.
In addition to graphs, the module may cover other topics in combinatorics such as: problems in extremal set theory, enumerative problems, Principle of Inclusion and Exclusion, and, for M-level students, Ramsey theory, computational complexity and the P versus NP problem.

MA598 Project on Financial Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn and Spring	H	15 (7.5)	50% Coursework, 50% Project	

Contact Hours

9 workshops/group meeting with supervisor

Learning Outcomes

Depending on the particular topics offered and written up by the student, on successful completion of this module, students will:
a) have appreciated an area of financial mathematics in more depth than in taught courses by carrying out investigations;
b) have developed skills in mathematical computation relevant to the topic;
c) be able to draw conclusions from statistical data, mathematical calculations and/or computer output;
d) have a reasonable ability to apply mathematical concepts and statistical techniques in a particular context;
e) have written a reasonably coherent account of an area of financial mathematics;
f) have performed computations that show their understanding of the techniques relevant to the topic;
g) have improved their ability in mathematical and statistical modelling of particular problems

Method of Assessment

50% Coursework, 50% Project

Pre-requisites

MA517 Corporate Finance for Financial Mathematicians; MA518 Probability and Measure Theory; MA535 Portfolio Theory and Asset Pricing Models.

Synopsis *

Financial Mathematicians employ a wide range of skills when collaborating on work-related projects. This module is designed to give students the opportunity to experience what it is like to work on such a project, and to develop the team-working, communication, time management and problem-solving skills that are vital in the workplace. Students are arranged into small teams, with each team working together under the guidance of a supervisor to produce a single written report, worth 50% of the total module mark. In addition, each student will submit project-related coursework, and coursework related to the Key Skills workshops attended in the Autumn Term. Each of these coursework elements will contribute a further 25% to the total module mark. The syllabus is determined by the topics offered by supervisors. A range of topics will be available, with many replicating the 'real-world' work that Financial Mathematicians undertake in their professional lives.

MA601 Individual Project in Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn and Spring	H	30 (15)	100% Project	Waterstraat Dr N

Contact Hours

Up to 6 hours with project supervisor, approx. 3 hours of key skills workshops

Learning Outcomes

The intended subject specific learning outcomes. Upon successful completion of the module students will:
a. have appreciated a particular area of mathematical thought or mathematical exposition in greater depth than in previous taught courses;
b. have developed skills in mathematical computation and/or communication relevant to the topic;
c. be able to draw conclusions from statistical data, mathematical calculations or computer output;
d. have a reasonable ability to apply mathematical concepts and/or statistical techniques in a particular context;
e. have written a reasonably coherent account of an area of mathematical thought, or a statistical method;
f. have performed computations that show their understanding of the techniques relevant to the topic;
g. have improved their ability in mathematical and statistical modelling of particular problems.

The intended generic learning outcomes. On successful completion of the Module, students will have developed:
a. improved communication skills;
b. enhanced intellectual independence;
c. relevant computing skills, including use of appropriate document preparation and word-processing packages;
d. improved problem solving skills
e. awareness of important issues relating to good written presentation of results;
f. greater ability to select material from source texts, either recommended to or found by the student, and shown awareness of the relationship of the material to background and to more advanced material;
g. their ability for independent learning and time management.

Method of Assessment

100% Project

Synopsis *

NB: Only for Mathematics with Secondary Education students.

This module provides an opportunity for students on the Mathematics with Secondary Education programme to explore and research a topic in mathematics or statistics that is of interest to the student. Under the guidance of a supervisor, the student will engage in self-directed study to produce a dissertation. Outline syllabus: This is determined by the topic of the project. Indicative mathematics titles include the following: Knot theory; Logistic map; Totally non-negative matrices; Signed permutations and the four colour theorem; Generating functions; Latin squares; Teaching further Linear Algebra; Graph theory; Exploring mathematics with origami; Classical invariant theory; Zeta functions; Foundations of the real numbers; Euler's formula; Creative use of random numbers to teach Statistics; The National Lottery; Circular data.

MA603 Introduction to Lie Groups and Lie Algebras

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48 lectures and example classes

Learning Outcomes

On successful completion of this module, H-level students will
(i) be aware of the range of algebraic, geometric and analytic issues that the study of Lie groups and Lie algebras entail, be able to reason confidently from algebraic definitions such as ideals, bilinear forms, representations and root spaces, be able to calculate confidently with basic constructions such as vector fields, Lie brackets, exponentials, and adjoint representations, and be able to determine the Lie algebra of a Lie group and in particular to understand its nature as a tangent space to the group;
(ii) have developed intuition for the structure of the main examples of Lie groups and Lie algebras that arise in applications, including nonlinear Lie group actions;
(iii) developed awareness of non-commutative phenomena;
(iv) be aware of topics which are an important tool of research in many areas of Mathematics, Physics and Chemistry.
(v) have understood and be able to discuss the role played by Lie groups and algebras in at least one application area in detail;
(vi) have used the computer algebra package MAPLE to perform calculations in specified Lie groups and Lie algebras.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

K. Tapp, Matrix groups for undergraduates, Student Mathematical Library 29 American Math.Society, 2005.
A. Fässler and E. Stiefel, Group Theoretical Methods and their applications, Boston, Birkh□auser,1992.

Pre-requisites

MA553 Linear Algebra or equivalent

Synopsis *

Lie groups and their associated Lie algebras are studied by both pure and applied mathematicians and by physicists; this is a topic renowned for both its mathematical beauty and its immense utility. Lie groups include translation, rotation and scaling groups as well as unitary, symplectic and special linear matrix groups. We will study in detail the lower dimensional groups that arise in many applications, and more general theory such as the structure of their associated Lie algebras. Special topics include a look at the lowest dimensional exceptional Lie group G2, and Lie group actions and their invariants.

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor

Contact Hours

42-48 lectures and example classes

Learning Outcomes

On successful completion of this module, H–level students will have increased their knowledge, understanding, intuition and computational expertise in:
(a) detecting symmetries and common patterns;
(b) using group theory to calculate with symmetries;
(c) the distinction and classification of objects up to equivalences and symmetries;
(d) the use of "normal forms" and "invariants" to distinguish symmetry classes.

They will also have:

(e) an enhanced ability to correctly formulate classification problems and solve them efficiently;
(f) an appreciation of algorithms and computational methods in algebra and group theory;
(g) consolidated a variety of tools from abstract algebra to model and classify concrete objects and configurations.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Group theory:
M. Aschbacher: Finite Group Theory (Cambridge Studies in Advanced Mathematics), Cambridge University Press, 2000,
B. Baumslag and B. Chandler: Schaum's Outline of Group Theory, McGraw Hill Professional, 1968,

Knot theory:
C. Livingston, Knot theory, Mathematical Association of America, 1993,

Pre-requisites

MA553 Linear Algebra and MA565 Groups and Rings

Synopsis *

In this module we will study certain configurations with symmetries as they arise in real world applications. Examples include knots described by "admissible diagrams" or chemical structures described by “colouring patterns”. Different diagrams and patterns can describe essentially the same structure, so the problem of classification up to equivalence arises. This will be solved by attaching “invariants” which are then put in “normal form” to distinguish them. The syllabus will be as follows: (a) Review of basic methods from linear algebra, group theory and discrete mathematics; (b) Permutation groups, transitivity, primitivity, Burnside formula; (c) Finitely generated Abelian groups; (d) Applications to knot theory, Reidemeister moves, the Abelian knot group; (e) Examples, observations, generalizations and proofs.

MA607 Quantum Mechanics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Dunning Dr C

Contact Hours

36

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of introductory quantum mechanics
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: potential wells and barriers in one dimension and the treatment of eigenvalue problems in quantum mechanics.
3 apply key aspects of quantum mechanics in well-defined contexts, showing judgement in the selection and application of tools and techniques.

On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources.
2 understand logical arguments, identifying the assumptions made and the conclusions drawn
3 communicate straightforward arguments and conclusions reasonably accurately and clearly
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working
5 solve problems relating to qualitative and quantitative information
6 communicate technical material competently
7 demonstrate an increased level of skill in numeracy and computation
8 demonstrate the acquisition of the study skills needed for continuing professional development

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

There is no essential reading or core text.
Background reading for level 6 and 7 students:
• F W Byron, "Mathematics of classical and quantum physics", Addison-Wesley, (1970)
• A Durrant, "Quantum Physics of Matter", Institute of Physics (2000)
• J Manners, “Quantum Physics: An introduction”, Institute of Physics (2000)
• A I M Rae, “Quantum Physics: A Beginner's Guide”, Oneworld Publications (2005)
• R Shankar, “Principles of quantum mechanics”, Plenum Press (1994)
• J J Sakurai, “Modern quantum mechanics”, Addison-Wesley (1994)

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA321 (Calculus and Mathematical Modelling), MA322 (Proofs and Numbers), MA323 (Matrices and Probability), MA325 (From Geometry to Algebra), MA552 (Analysis), MA553 (Linear Algebra), MA588 (Mathematical Techniques and Differential Equations) or students must have studied material equivalent to that covered in these modules.
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST4002 (Applications of Mathematics), MAST4004 (Linear Algebra), MAST4006 (Mathematical Methods 1), MAST4007 (Mathematical Methods 2), MAST5005 (Linear PDEs), MAST5004 (Lagrangian and Hamiltonian dynamics) or students must have studied material equivalent to that covered in these modules.
Co-requisite: None

Synopsis *

Quantum mechanics provides an accurate description of nature on a subatomic scale, where the standard rules of classical mechanics fail. It is an essential component of modern technology and has a wide range of fascinating applications. This module introduces some of the key concepts of quantum mechanics from a mathematical point of view.
The joint level 6/level 7 curriculum will consist of the following:
• The necessity for quantum mechanics. The wavefunction and Born's probabilistic interpretation.
• Solutions of the time-dependent and time-independent Schrödinger equation for a selection of simple potentials in one dimension.
• Reflection and transmission of particles incident onto a potential barrier. Probability flux. Tunnelling of particles.
• Wavefunctions and states, Hermitian operators, outcomes and collapse of the wavefunction.
• Heisenberg's uncertainty principle.
Additional topics may include applications of quantum theory to physical systems, quantum computing or recent developments in the quantum world.

MA609 Applied Differential Geometry

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48 lectures and example classes

Learning Outcomes

On successful completion of this module, students will:
a) understand basic geometric objects such as curves and surfaces;
b) be able to construct and manipulate the Frenet frames for plane and space curves;
c) be able to analyse surfaces in three-dimensional space by calculating various quantities, e.g., the first and second fundamental forms, Gauss curvatures and mean curvatures;
d) gain an understanding of basic geometric concepts such as geodesics and minimal surfaces.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

V A Toponogov, "Differential Geometry of Curves and Surfaces A Concise Guide'', Birkhäuser Boston, 2006 (E-book available in the Templeman Library).
M P Carmo, "Differential Geometry of Curves and Surfaces A Concise Guide'', Prentice-Hall, 1976.
V Y Rovenskii, "Geometry of Curves and Surfaces with MAPLE'', Birkhäuser Boston, 2000.

Pre-requisites

MA321, MA322, MA323, MA552, MA553, MA588

Synopsis *

The main aim is to give an introduction to the basics of differential geometry, keeping in mind the recent application in mathematical physics and the analysis of pattern recognition.
The synopsis may include:
(a) Theory of curves: Regular plane and space curves. Tangent vectors. Arclength parameterisation. Curvature and Euclidean invariants. The Frenet formula.

(b) Geometry of surfaces: Regular parameterised surface. The tangent plane. Curvature of a curve on a surface. First and second fundament forms. Shape operator. Gaussian curvature and mean curvature.
(c) Geodesics and Minimal surfaces: The Christoffel symbols. Geodesics. The Euler-Lagrange equations. The Gauss-Bonnet Theorem. Minimal surfaces.

Possible other topics may include: Evolution of curves and surfaces as integrable systems: Invariant curve evolution. The mean curvature flow. Riemannian metrics, connections, curvatures and geodesics.
In addition, for M-level students, the connection with integrable systems; curves evolution in Riemannian manifolds with constant curvature and Moving frames.

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor

Contact Hours

42-48 lectures and example classes

Learning Outcomes

On successful completion of this module, students will:
a) be able to work with fundamental concepts in functional analysis, such as linear operators and functionals;
b) have a grasp of formal definitions and rigorous proofs in analysis;
c) have gained an appreciation of a wider context in which previously encountered concepts from analysis, such as convergence and continuity, can be used;
d) be able to apply abstract ideas to concrete problems in analysis;
e) appreciate differences between analysis in infinite and finite dimensional spaces;
f) be aware of applications of basic techniques and theorems of functional analysis in other areas of mathematics, e.g., approximation theory, and the theory of ordinary differential equations

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

1) Introductory Functional Analysis with Applications, Erwin Kreyszig, John Wiley, 1978.
2) Principles of Mathematical Analysis. Walter Rudin, International Series in Pure and Applied Mathematics, McGraw-Hill, 1976 3rd edition.
3) Beginning Functional Analysis, Karen Saxe, Springer, 2002.
4) Introduction to Functional Analysis, Angus E.Taylor, David C.Lay, John Wiley, 1980 2nd edition.

Pre-requisites

MA321 (Calculus and Mathematical Modelling), MA322 (Proofs and Numbers), MA323 (Matrices and Probability) at Stage 1 and MA552 (Analysis), MA553 (Linear Algebra) at Stage 2, or students must have studied material equivalent to that covered in these modules.

Synopsis *

This module will give an introduction to one of the main areas underpinning research in Analysis today: Functional Analysis, which has applications in many sciences, in particular in the modern theory of solutions of partial differential equations. As well as giving the main definitions and theorems in the area, the module will focus on applications, in particular to differential equations and in approximation theory. The following topics will be covered in the module: 1) Linear spaces: Normed and Banach spaces, Inner-product and Hilbert spaces, examples 2) Linear operators and functionals: bounded linear operators, functionals, dual spaces, reflexive spaces, adjoint operators, selfadjoint operators, examples 3) Fundamental theorems: Hahn-Banach, Uniform boundedness principle, Open mapping & Closed graph theorem, Baire Category theorem 4) Fixed point theorems and applications to differential and integral equations 5) Applications in approximation theory: best approximation in Hilbert space, approximation of continuous functions by polynomials. Possible additional topic: Spectral theory of bounded linear operators, weak and weak* topologies, algebras of bounded linear operators.

MA617 Asymptotics and Perturbation Methods

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48 lectures and example classes

Learning Outcomes

On successful completion of this module, students will:

a) have developed a familiarity with the use of asymptotic techniques in the study of integrals and differential equations;
b) be able to obtain asymptotic approximations of various types of integrals;
c) be able to determine approximate solutions of linear differential equations;
d) be able to generate matched asymptotic expansions for singular perturbation and boundary layer problems
e) be able to use WKB (Wentzel-Kramers-Brillouin), multiple scales and related methods to obtain asymptotic expansions of solutions of some differential equations

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

14. Indicative Reading List
C M Bender and S A Orszag, "Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory", Springer-Verlag, New York (1999)
J D Murray, “Asymptotic Analysis”, Springer-Verlag, New York (1997)
All books are available in the Templeman Library.

Pre-requisites

MA321 (Calculus and Mathematical Modelling), MA322 (Proofs and Numbers), MA323 (Matrices and Probability) at Stage 1 and MA552 (Analysis), MA553 (Linear Algebra), MA588 (Mathematical Techniques and Differential Equations) at Stage 2, or students must have studied material equivalent to that covered in these modules.

Synopsis *

The lectures will introduce students to asymptotic and perturbation methods for the approximate evaluation of integrals and to obtain approximations for solutions of ordinary differential equations. These methods are widely used in the study of physically significant differential equations which arise in Applied Mathematics, Physics and Engineering. The material is chosen so as to demonstrate a range of mathematical techniques available and to illustrate some different applications which are amenable to such analysis.

MA636 Stochastic Processes

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Zhang Prof J (MA)
1	Canterbury	Autumn	H	15 (7.5)	90% Exam, 10% Coursework	Zhang Prof J (MA)

Contact Hours

48 hours

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of stochastic modelling;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: random walks, discrete and continuous time Markov chains, queues and branching processes;
3 apply key aspects of stochastic modelling in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes.
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly and communicate technical material competently;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle);
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Ross, S.M. (1996) Stochastic Processes. New York, Wiley.
Breuer, L. and Baum, D. (2005) An introduction to Queueing Theory and Matrix-Analytic Methods. Springer, Dordrecht.
Jones, P.W. and Smith, P. (2001) Stochastic Processes: An Introduction. London, Arnold.
Karlin, S., Taylor, H.M. (1998) A First Course in Stochastic Processes. 3rd Edition, Academic Press, London.
Ross, S.M. (1970) Applied Probability Models with Optimization Applications. Holden-Day, San Francisco.
Cox, D.R. and Miller, H.D. (1965) The Theory of Stochastic Processes. Chapman & Hall/CRC.

Pre-requisites

Prerequisite and co-requisite modules
Level 6:
For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA321 (Calculus and Mathematical Modelling), MA322 (Proofs and Numbers), and either MA323 (Matrices and Probability) and MA306 (Statistics) or MA319 (Probability and Inference for Actuarial Science) and MA326 (Matrices and Computing); MA552 (Analysis), MA553 (Linear Algebra) and either MA629 (Probability and Inference) or MA529 (Probability and Statistics for Actuarial Science 2); or their equivalents.
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST4009 (Probability), MAST4011 (Statistics), MAST4006 (Mathematical Methods 1), MAST4007 (Mathematical Methods 2), either MAST4010 (Real Analysis 1) and MAST4004 (Linear Algebra) or MAST4005 (Linear Mathematics), and MAST5007 Mathematical Statistics; or their equivalents.
Co-requisite: None

Synopsis *

Introduction: Principles and examples of stochastic modelling, types of stochastic process, Markov property and Markov processes, short-term and long-run properties. Applications in various research areas.
Random walks: The simple random walk. Walk with two absorbing barriers. First–step decomposition technique. Probabilities of absorption. Duration of walk. Application of results to other simple random walks. General random walks. Applications.
Discrete time Markov chains: n–step transition probabilities. Chapman-Kolmogorov equations. Classification of states. Equilibrium and stationary distribution. Mean recurrence times. Simple estimation of transition probabilities. Time inhomogeneous chains. Elementary renewal theory. Simulations. Applications.
Continuous time Markov chains: Transition probability functions. Generator matrix. Kolmogorov forward and backward equations. Poisson process. Birth and death processes. Time inhomogeneous chains. Renewal processes. Applications.
Queues and branching processes: Properties of queues - arrivals, service time, length of the queue, waiting times, busy periods. The single-server queue and its stationary behaviour. Queues with several servers. Branching processes. Applications.

Marks on this module can count towards exemption from the professional examination CT4 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA639 Time Series Modelling and Simulation

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	90% Exam, 10% Coursework	
2	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Kume Dr A
2	Canterbury	Spring	H	15 (7.5)	90% Exam, 10% Coursework	Kume Dr A

Contact Hours

46

Learning Outcomes

The intended subject specific learning outcomes
On successfully completing this module students will be able to:
1 demonstrate systematic understanding of key aspects of time series modelling and simulation;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: ARIMA and GARCH time series models including those modelling seasonality, main methods for simulating random variates;
3 apply key aspects of time series modelling in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes
On successfully completing this module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly and communicate technical material competently;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle);
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Enders, W. (2004), Applied Econometric Time Series, New York: Wiley.
Brockwell, P.J., and Davis, R. A. (2002), Introduction to Time Series Analysis and Forecasting, New York: Springer-Verlag.
Morgan, B. J. T. (1984), Elements of Simulation, London: Chapman & Hall/CRC.

Pre-requisites

MA5507 (Mathematical Statistics) or equivalent

Synopsis *

A time series is a collection of observations made sequentially in time. Examples occur in a variety of fields, ranging from economics to engineering, and methods of analysing time series constitute an important area of statistics. This module focuses initially on various time series models, including some recent developments, and provides modern statistical tools for their analysis. The second part of the module covers extensively simulation methods. These methods are becoming increasingly important tools as simulation models can be easily designed and run on modern PCs. Various practical examples are considered to help students tackle the analysis of real data.The syllabus includes: Difference equations, Stationary Time Series: ARMA process. Nonstationary Processes: ARIMA Model Building and Testing: Estimation, Box Jenkins, Criteria for choosing between models, Diagnostic tests.Forecasting: Box-Jenkins, Prediction bounds. Testing for Trends and Unit Roots: Dickey-Fuller, ADF, Structural change, Trend-stationarity vs difference stationarity. Seasonality and Volatility: ARCH, GARCH, ML estimation. Multiequation Time Series Models: Spectral Analysis. Generation of pseudo – random numbers, simulation methods: inverse transform and acceptance-rejection, design issues and sensitivity analysis.

Marks on this module can count towards exemption from the professional examination CT6 of the Institute and Faculty of Actuaries. Please see http://www.kent.ac.uk/casri/Accreditation/index.html for further details.

MA6503 Communicating Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	100% Coursework	Wood Dr I

Contact Hours

12 workshops

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 convey a systematic understanding of key aspects of a topic in mathematics, statistics or financial mathematics through scientific writing and oral presentation;
2 demonstrate a reasonable level of skill in written and oral presentation of a topic in mathematics, statistics or financial mathematics;
3 show judgement in the selection and presentation of material to communicate with both specialist and non-specialist audiences.

On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 communicate straightforward arguments and conclusions reasonably accurately and clearly;
3 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
4 make competent use of information technology skills such as word-processing and online resources (Moodle);
5 communicate technical and non-technical material competently;
6 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

100% Coursework

Preliminary Reading

Stephen G. Krantz,, A Primer of Mathematical Writing, A.M.S., 1997.
Kevin Houston, How to think like a mathematician: a companion to undergraduate mathematics, C.U.P., 2009.
Hilary Glasman-Deal, Science Research Writing for Non-Native Speakers of English, Imperial College Press, 2009.
Anne E. Greene, Writing science in plain English, University of Chicago Press, 2013.
Alan Beardon, Creative Mathematics: a gateway to research, C.U.P., 2009.
Carmine Gallo, Talk Like TED : The 9 Public Speaking Secrets of the World's Top Minds, Macmillan, 2014.
Toby Oetiker, The not so short introduction to LaTeX, available online, 1995.

Synopsis *

The aim of this module is to equip students with the skills needed to communicate mathematics effectively to the world. This module is supported by a series of workshops covering various forms of written and oral communication. Each student will choose a topic in mathematics, statistics or financial mathematics from a published list on which to base their three coursework assessments which include a scientific writing assessment and an oral presentation.

MA6508 Applied Statistical Modelling 1

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Zhang Prof J (MA)

Contact Hours

This module will be delivered using lectures and terminal classes. Lectures will be used to discuss the key theoretical ideas and their application. The terminal classes will be used to develop skills in statistical modelling using R. Exercise sheets will be used to develop students' understanding and there will be an emphasis on practical data analysis skills. In addition, level 6 students are set a directed reading task to cover logistic regression, with access to staff support.
Total number of study hours: 150.

Learning Outcomes

On successfully completing the level 6 module students will be able to:
8.5 demonstrate systematic understanding of key aspects of statistical modelling using linear regression models, likelihood estimation and logistic regression;
8.6 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation in the following areas: simple linear regression, linear models including estimation and diagnostics, one-way analysis of variance, maximum likelihood estimation, model selection strategies, estimation for the multivariate normal, partial and multiple correlation, logistic regression;
8.7 apply key aspects of statistical modelling using regression models and likelihood estimation in well-defined contexts, showing judgement in the selection and application of tools and techniques;
8.8 show judgement in the application of R.

Method of Assessment

The module will be assessed by examination (80%) and coursework (20%). This coursework mark alone will not be sufficient to demonstrate the student's level of achievement on the module.
Coursework: Level 6 students will submit two pieces of coursework for assessment, one consisting of selected questions and the other an assignment relating to the directed reading task. Both assessments will require the use of R.
Examination: There will be a 2-hour written examination in the Summer term, with variants for level 5 and level 6 students, that consists of multipart questions requiring a mix of short and long answers.

Preliminary Reading

Reading List (Indicative list, current at time of publication. Reading lists will be published annually)
Chatterjee, S., and Hadi, A.S. (2012) Regression analysis by example. 5th edition. Hoboken Wiley.
Draper, N. R., and Smith, H. (1998) Applied regression analysis. 3rd edition. Wiley.
Freedman, D. (2005) Statistical models: theory and practice. Cambridge University Press.

Pre-requisites

MAST4009 (Probability); MAST4011 (Statistics); MAST4004 (Linear Algebra) or MAST4005 (Linear Mathematics); MAST4006 (Mathematical Methods 1); MAST4007 (Mathematical Methods 2) or equivalent.

Synopsis *

Simple linear regression; the method of least squares; sums of squares; the ANOVA table; residuals and diagnostics; matrix formulation of the general linear model; prediction; variable selection; one-way analysis of variance; practical regression analysis using software; logistic regression.

MA6510 Advances in Statistics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Zhang Prof J (MA)

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of some selected topics within modern statistics;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation in the following areas: modern statistical modelling and statistical methods;
3 apply key aspects of some selected topics within modern statistics in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the application of R.

The intended generic learning outcomes:
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (moodle), internet communication;
7 communicate technical and non-technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

The reading list will depend on the topics offered; for the example topics the list is:
a) Statistical Ecology
McCrea, R. S. and Morgan, B. J. T. (2014): Analysis of capture-recapture data (Chapman & Hall / CRC)
b) Survival Analysis
Collet, D. (2003): Modelling survival data in medical research, Second Edition (Chapman & Hall / CRC)
c) Regression models with many variables
Hastie, T., Tibshirani, R. and Wainwright, M. J. (2015): Statistical Learning with Sparsity (Chapman & Hall / CRC).
d) Modern nonparametric statistics
Larry Wasserman (2006): All of Nonparametric Statistics, Springer: New York.

Pre-requisites

MAST4009 (Probability); MAST4011 (Statistics); MA5007 (Mathematical Statistics) or MAST5001 (Applied Statistical Modelling 1)

Synopsis *

Each year three topics will be offered and will reflect recent advances in statistical modelling and statistical methodology. Example topics are:
a) Statistical Ecology: Understanding demographic parameters and how they are used to model population dynamics. Estimating abundance and the effect of heterogeneity. Models for estimating survival probabilities. Multi-site and multi-state models. Classical model-selection. Complex models. Case studies.
b) Survival analysis: Survival data, types of censoring. Failure times and hazard functions; Accelerated failure time model. Parametric models, exponential, piecewise exponential, Weibull. Nonparametric estimates: the Kaplan-Meier estimator, and asymptotic confidence regions. Parametric inference. Survival data with covariates. Proportional hazards. Cox's model and inference. Computer software: R and WinBUGS.
c) Regression models with many variables: Examples of high-dimensional problems; Penalized maximum likelihood; Ridge regression; non-negative garrote; Lasso and adaptive Lasso estimation; LARS algorithm; Oracle property; Elastic Net; Group lasso.
d) Modern nonparametric statistics: Bias-variance trade-off, Kernel density estimation, Kernel smoothing, Locally linear and locally quadratic estimation, basis function methods.

MA6512 Applied Statistical Modelling 2

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	50% Coursework, 50% Exam	Cole Dr D

Contact Hours

32

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the module students will be able to:
1 demonstrate systematic understanding of and a reasonable level of skill in the professional skills required by a practising statistician;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: data presentation, hypothesis testing, linear and generalised linear models;
3 apply key aspects of practical data analysis and reporting in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the selection and application of statistical analysis techniques using a range of statistical software, e.g. R, SPSS and Excel.

The intended generic learning outcomes:
On successfully completing the module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as word-processing and spreadsheet use, online resources (Moodle), internet communication;
7 communicate technical and non-technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development;
10 give an oral presentation;
11 work effectively as a member of a team.

Method of Assessment

50% examination, 50% coursework

Preliminary Reading

Chatfield, C. (1995). Problem Solving: a Statistician's Guide. Second edition. London: Chapman & Hall.
Cox, D.R. & Snell, E.J. (1981). Applied Statistics: Principles and Examples. London: Chapman & Hall.
Dobson, A.J. & Barnett, A. (2008). An Introduction to Generalized Linear Models. Third edition. London: Chapman & Hall.
Hand, D.J. & Everitt, B.S. (1987). The Statistical Consultant in Action.
Sprent, P. & Smeeton, N.C. (2007). Applied Nonparametric Statistical Methods. Fourth edition. London: Chapman & Hall.

Pre-requisites

Pre-requisite: MAST4009 (Probability), MAST4011 (Statistics), MAST5001 (Applied Statistical Modelling 1)
Co-requisite: None

Synopsis *

This is a practical module to develop the skills required by a professional statistician (report writing, consultancy, presentation, wider appreciation of assumptions underlying methods, selection and application of analysis method, researching methods).
Software: R, SPSS and Excel (where appropriate/possible). Report writing in Word. PowerPoint for presentations.
• Presentation of data
• Report writing and presentation skills
• Hypothesis testing: formulating questions, converting to hypotheses, parametric and non-parametric methods and their assumptions, selection of appropriate method, application and reporting. Use of resources to explore and apply additional tests. Parametric and non-parametric tests include, but are not limited to, t-tests, likelihood ratio tests, score tests, Wald test, chi-squared tests, Mann Whitney U-test, Wilcoxon signed rank test, McNemar's test.
• Linear and Generalised Linear Models: simple linear and multiple regression, ANOVA and ANCOVA, understanding the limitations of linear regression, generalised linear models, selecting the appropriate distribution for the data set, understanding the difference between fixed and random effects, fitting models with random effects, model selection.
• Consultancy skills: group work exercise(s)

MA6517 Functions of a Complex Variable

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Wang Dr JP

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the module students will be able to:
1 demonstrate systematic understanding of key aspects of complex analysis;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: power series, analytic functions, contour integrals, singularities, residues, Taylor and Laurent series, the residue theorem;
3 apply key aspects of complex analysis in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes:
On successfully completing the module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

H.A. Priestley, Introduction to Complex Analysis, Oxford University Press, 2003
M.R. Spiegel, Complex Variables, McGraw-Hill, 1964
J.H. Mathews & R.W Howell, Complex Analysis for Mathematics and Engineering, Jones and Bartlett 5th ed., 2006
I Stewart & D Tall, Complex Analysis, Cambridge, 2004

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA552 (Analysis)
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST4010 (Real Analysis 1) and MAST5013 (Real Analysis 2)
Co-requisite: None

Synopsis *

• Revision of complex numbers, the complex plane, de Moivre's and Euler's theorems, roots of unity, triangle inequality
• Sequences and limits: Convergence of a sequence in the complex plane. Absolute convergence of complex series. Criteria for convergence. Power series, radius of convergence
• Complex functions: Domains, continuity, complex differentiation. Differentiation of power series. Complex exponential and logarithm, trigonometric, hyperbolic functions. Cauchy-Riemann equations
• Complex Integration: Jordan curves, winding numbers. Cauchy's Theorem. Analytic functions. Liouville's Theorem, Maximum Modulus Theorem
• Singularities of functions: poles, classification of singularities. Residues. Laurent expansions. Applications of Cauchy's theorem. The residue theorem. Evaluation of real integrals.
Possible additional topics may include Rouche's Theorem, other proofs of the Fundamental Theorem of Algebra, conformal mappings, Mobius mappings, elementary Riemann surfaces, and harmonic functions.

MA6518 Games and Strategy

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Lemmens Dr B

Contact Hours

40

Learning Outcomes

On successfully completing the module students will be able to:
1 demonstrate systematic understanding of key aspects of game theory;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: combinatorial games, two-player zero-sum games, general and multiplayer games, optimal strategies and equilibria in games;
3 apply key aspects of game theory in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Game Theory: A playful introduction, M. DeVos and D.A. Kent, Student Mathematical Library, vol. 80, Amer. Math. Soc., 2016.
Playing for real: A text on game theory, K. Binmore, Oxford Univ. Press, 2007.

Pre-requisites

Pre-requisite: MAST4004 (Linear Algebra) or MAST4005 (Linear Mathematics)
Co-requisite: None

Synopsis *

Combinatorial games, game trees, strategy, classification of positions. Two-player zero-sum games, security levels, pure and mixed strategies, von Neumann's minimax theorem. Solving zero-sum two player games using linear programming. Arbitrary sum games, utility, and matrix games. Nash equilibrium, Nash equilibrium theorem, applications, and cooperation. Multi-player games, coalitions, and the Shapley value.

MA6522 Integrable Systems

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Wang Dr JP

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of integrable systems;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: nonlinear differential equations, Hamiltonian systems, nonlinear difference equations;
3 apply key aspects of integrable systems in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes:
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle) and internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

O. Babelon, D. Bernard and M. Talon, Introduction to Classical Integrable Systems, Cambridge Monographs on Mathematical Physics, Cambridge University Press, 2003.
M.J. Ablowitz and P.A. Clarkson, Solitons, Nonlinear Evolution Equations and Inverse Scattering, London Mathematical Society Lecture Note Series 149, Cambridge University Press, 1992.
P.G. Drazin and R.S. Johnson, Solitons: an introduction, Cambridge Texts in Applied Mathematics 2, Cambridge University Press, 1989.
J. Hietarinta, N. Joshi and F. W. Nijhoff, Discrete Systems and Integrability, Cambridge Texts in Applied Mathematics, Cambridge University Press, 2016.

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA552 (Analysis), MA588 (Mathematical Techniques and Differential Equations);

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST5013 (Real Analysis 2); MAST5005 (Linear Partial Differential Equations)
Recommended: MAST5004 (Lagrangian and Hamiltonian Dynamics); MAST6002 (Linear and Nonlinear Waves).

Synopsis *

Integrable systems are special dynamical systems which can be solved exactly in some sense. They arise in a variety of settings, ranging from Hamiltonian systems and nonlinear wave equations to difference equations. This module covers the origins of the subject as well as modern topics like integrable maps and lattice equations.
- Liouville integrability in classical mechanics. Hamiltonian mechanics. Canonical symplectic form and Poisson brackets. Liouville's theorem (statement and examples). Lax pairs for finite-dimensional systems.
- Soliton equations. History and physical origins (e.g. Korteweg-de Vries and/or sine-Gordon). Conservation laws. Hamiltonian formalism. Lax pairs.
- Construction of solitons. Introduction to inverse scattering. Darboux-Bäcklund transformations. Hirota's method.
- Discrete integrability. Symplectic maps. Liouville's theorem (discrete version). Integrable lattice equations. Discrete Lax pairs with examples.

MA6524 Metric and Normed Spaces

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

38

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of metric and normed spaces;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: convergence and continuity of maps in metric spaces, contraction mappings, completeness of spaces, spaces of continuous functions, linear operators;
3 apply key aspects of normed spaces in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes.
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

G. Cohen: A Course in Modern Analysis and its Applications. Cambridge University Press (2003).
J.R. Giles: Introduction to the Analysis of Normed Linear Spaces. Cambridge University Press (2000).
V.L. Hansen: Functional Analysis – Entering Hilbert Space. World Scientific (2006).
B. Rynne, M. Youngson: Linear Functional Analysis. Springer (2008).
W.A. Sutherland: Introduction to Metric and Topological Spaces. Oxford University Press (2002).

Synopsis *

Many fundamental concepts and results in mathematical analysis in real and complex spaces rely on the notion of `being close'. It turns out that one can do mathematical analysis in a much wider context as long as there is a distance (or metric) that provides a way to measure closeness. Such spaces are called metric spaces and include the important class of normed spaces. In this module you will be introduced to theory and applications of metric and normed spaces. Much of the theory was developed in the previous century and has been a driving force in modern analysis.

MA6528 Principles of Data Collection

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Laurence Dr A

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcome
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of sampling and experimental design;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: sampling, questionnaire design, analysis of variance, clinical trial design;
3 apply key aspects of sampling and experimental design in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the application of R for the analysis of data from experiments.

The intended generic learning outcomes:
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (moodle), internet communication;
7 communicate technical and non-technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Barnett, V. (2002) Sample Survey Principles and Methods. 3rd edition. New York, Wiley.
Cox, D.R. (1992) Planning of Experiments. New York, Wiley.
Cochran, W.G. & Cox, G.M. (1992) Experimental Designs. 2nd edition. New York, Wiley.
Cox. D.R & Reid, N. (2000) The Theory of the Design of Experiments. Boca Raton, Chapman & Hall/CRC
Lawson, J. (2015) Design and Analysis of Experiments with R. Boca Raton, Chapman & Hall/CRC.
Matthews, J. N. S. (2000) An Introduction to Randomized Controlled Clinical Trials. 2nd edition. Boca Raton, Chapman & Hall/CRC.

Pre-requisites

Pre-requisite: MAST4009 (Probability), MAST4011 (Statistics) and at least one of MAST5007 (Mathematical statistics) and MAST5001 (Applied statistical modelling 1)

Synopsis *

Sampling: Simple random sampling. Sampling for proportions and percentages. Estimation of sample size. Stratified sampling. Systematic sampling. Ratio and regression estimates. Cluster sampling. Multi-stage sampling and design effect. Questionnaire design. Response bias and non-response.
General principles of experimental design: blocking, randomization, replication. One-way ANOVA. Two-way ANOVA. Orthogonal and non-orthogonal designs. Factorial designs: confounding, fractional replication. Analysis of covariance.
Design of clinical trials: blinding, placebos, eligibility, ethics, data monitoring and interim analysis. Good clinical practice, the statistical analysis plan, the protocol. Equivalence and noninferiority. Sample size. Phase I, II, III and IV trials. Parallel group trials. Multicentre trials.

MA6529 Statistical Learning

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Matechou Dr E

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of multivariate statistics and machine learning;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: multivariate statistics, mixture modelling and clustering, discriminant analysis and graphical models;
3 apply key aspects of multivariate statistics and machine learning in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the application of R.

The intended generic learning outcomes:
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (moodle), internet communication;
7 communicate technical and non-technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

D. F. Morrision (1990). Multivariate Statistical Methods, McGraw-Hill Series in Probability and Statistics
T. Hastie, R. Tibshirani and J. H. Friedman (2009). The Elements of Statistical Learning, Spring-Verlag.
K. P. Murphy (2012). Machine Learning: A Probabilistic Perspective, MIT Press.

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA306 (Statistics); MA323 (Probability and Matrices) or MA312 (Introduction to Financial Concepts); MA629 (Probability and Inference); MA632 (Regression Models)

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST4009 (Probability); MAST4011 (Statistics); MAST5007 (Mathematical Statistics) or MAST5001 (Applied Statistical Modelling 1)

Synopsis *

Multivariate normal distribution, Inference from multivariate normal samples, principal component analysis, mixture models, factor analysis, clustering methods, discrimination and classification, graphical models, the use of appropriate software.

MA6534 Derivative Markets

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Kalli Dr M

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the module students will be able to:
1 demonstrate systematic understanding of key aspects of the derivative markets;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: Futures markets, interest rate topics, interest rate derivatives and swap, trading strategies of future, forwards and options;
3 apply key aspects of the derivative markets in well-defined contexts, showing judgement in the selection and application of tools and techniques.

The intended generic learning outcomes:
On successfully completing the module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

John C. Hull, Fundamentals of Futures and Options markets, (8th Edition) Pearson, 2013
John C. Hull, Options, Futures and other Derivatives, (8th Edition) Pearson, 2011

Pre-requisites

MAST4003 Introduction to Finance

Synopsis *

Futures Markets: Mechanics, Hedging strategies
Interest rates: Type of rates, LIBOR, Repo, Spot, Forward
Determination of Forward and Future Prices: Short and long positions, forward prices
Interest Rate Derivatives and Swaps
Option Markets: Mechanics, Properties, trading strategies

MA6540 Financial Econometrics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Hadjiantoni Dr S

Contact Hours

34

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of financial time series data analysis;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of material in the following areas: ARIMA and GARCH model building, testing and estimation, model selection, forecasting, financial hypothesis testing and modelling in the context of asset returns, the efficient portfolio;
3 apply key aspects of financial time series data analysis in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 show judgement in the application of R.

The intended generic learning outcomes:
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly and communicate technical material competently;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (moodle);
7 communicate technical and non-technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Enders, W. (2004). Applied Econometric Time Series. New York: Wiley.
Brockwell, P.J. & Davis, R.A. (2002). Introduction to Time Series and Forecasting. New York: Springer.
Ruey S. Tsay (2002). Analysis of financial time series, New York: Wiley
Campbell, J.Y., Lo, A.W. and Mackinlay, A.C. (1997). The Econometrics of Financial Markets, New Jersey: Princeton University Press.
Lyuu Y. (2002). Financial Engineering and Computation. Cambridge University Press.

Pre-requisites

Pre-requisites: MAST4009 Probability, MAST4011 Statistics, MAST5001 Applied Statistical Modelling and MAST5007 Mathematical Statistics

Synopsis *

Overview of statistical methods. Stationary time series. Autocovariance and autocorrelation functions. Partial autocorrelation functions. ARMA processes. ARIMA model building, testing and estimation. Criteria for choosing between models. Forecasting. Cointegration. Prediction bounds. Asset return and risk. Term structure of interest rates. Distributional properties of asset returns. Testing for CAPM. Testing random walk hypothesis and predicting asset return. Sharpe ratio and efficient portfolio. Cross-section modelling and GMM. Estimate multifactor models. Financial applications of AR, MA, and ARMA. ARCH and GARCH models. Volatility processes. Simple applications of these techniques using R.

MA6591 Mathematics in the World of Finance

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Lynskey A

Contact Hours

42

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the module students will be able to:
1 demonstrate a systematic understanding of several important applications of mathematics in finance and an understanding of the work of the main practitioners of mathematical finance including actuaries, investment analysts and accountants;
2 demonstrate the capability to make sound judgements in accordance with the basic theories and concepts and demonstrate a reasonable level of skill in calculation and manipulation of the material in the following areas: time value of money, characteristics of different financial securities, valuation of securities, project evaluation and decisions, interest rates, loans, capital structure and the cost of capital;
3 apply key mathematical concepts and methods in well-defined contexts in finance, showing an ability to evaluate the appropriateness of different approaches to solving problems in this area.

The intended generic learning outcomes.
On successfully completing the module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Herbert B. Mayo, Basic Finance: An Introduction to Financial Institutions, Investments and Management, 10th Edition, South-Western College Pub, 2011.
Garratt, S.J. An introduction to the mathematics of finance. A deterministic approach, 2nd Edition, Butterworth-Heinemann, 2013.

Pre-requisites

MAST4010 (Real Analysis 1)

Synopsis *

This module provides an overview of analytical careers in finance and explores the mathematical techniques used by actuaries, accountants and financial analysts. Students will learn about different types of financials assets, such as shares, bonds and derivatives and how to work out how much they are worth. They will also look at different types of debt and learn how mortgages and other loans are calculated. Developing these themes, the module will explain how to use maths to make financial decisions, such as how much an investor should pay for a financial asset or how a company can decide which projects to invest in or how much money to borrow. Risk management is a vital part of most mathematical careers in finance so the module will also cover different mathematical techniques for measuring and mitigating financial risk.
Extension topics may include complex derivatives, economic theories of finance and the dangers of misusing mathematics.
The module provides an opportunity to apply complex mathematical techniques to important real-world questions and is excellent preparation for those considering a financial career.
Introduction to financial mathematics: Key uses of mathematics in finance; key practitioners of financial mathematics.
Financial valuation and cash flow analysis: Discounting, Interest rates and time requirements, Future and Present value.
Project Evaluation.
Characteristics and valuation of different financial securities: Debt capital, bonds and stocks, valuation of bonds and stocks.
Loans and interest rates: term structure of interest rates, spot and forward rates, types of loan, APR, loan schedules.
Capital structure and the cost of capital: Gearing, WACC, understanding betas.
Additional topics that may be covered: arbitrage and forward contracts, efficient markets hypothesis, pricing and valuing forward contracts, option pricing and the Black Scholes model, credit derivatives and systemic risks, limitations of mathematical modelling.

MA690 Symmetry Methods for Differential Equations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Mansfield Prof E

Contact Hours

36

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of symmetry methods for solving and simplifying scalar ordinary differential equations
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: calculation of Lie point symmetry generators, canonical coordinates and differential invariants; identification of invariant solutions; successive reduction of order, where the Lie algebra is solvable; construction of the general solution of a given ordinary differential equation
3 apply key aspects of Lie symmetry methods in well-defined contexts, showing judgement in the selection and application of tools and techniques

On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources.
2 understand logical arguments, identifying the assumptions made and the conclusions drawn
3 communicate straightforward arguments and conclusions reasonably accurately and clearly
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working
5 solve problems relating to qualitative and quantitative information
6 make competent use of information technology skills such as using online resources (Moodle).
7 communicate technical material competently
8 demonstrate an increased level of skill in numeracy and computation
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

P. E. Hydon, Symmetry Methods for Differential Equations, Cambridge University Press, (2000).
H. Stephani, Differential Equations: Their Solution Using Symmetries, Cambridge University Press, (1989).
G. W. Bluman and S. C. Anco, Symmetry and Integration Methods for Differential Equations, Springer, (2002)

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite modules: MA321 (Calculus and Mathematical Modelling); MA588 (Mathematical Techniques and Differential Equations)
Co-requisite modules: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite modules: MAST5005 (Linear partial differential equations), MAST5012 (Ordinary differential equations)
Co-requisite modules: None

Synopsis *

Over a century ago, the Norwegian mathematician Sophus Lie made a simple but profound observation: each well-known method for solving a class of ordinary differential equations (ODEs) uses a change of variables that exploits symmetries of the class. Lie went on to develop this idea into a systematic method for attacking the problem of solving unknown differential equations. Essentially, one can use mathematical tools to force a given differential equation to reveal whether or not it has certain symmetries – provided it has, they can be used to simplify or solve the equation. This module is designed to enable students to understand the mathematics behind Lie's methods and to become proficient in using these powerful tools.
The following topics are covered.
Introduction: Symmetries of geometrical objects, symmetries of some first-order ODEs, solution via symmetries.
Lie symmetries of first-order ODEs: The infinitesimal generator, canonical coordinates, invariant points, Lie symmetries and standard solution methods.
How to find Lie symmetries: The linearized symmetry condition, solution of overdetermined systems, the Lie algebra of point symmetry generators.
Solution of higher-order ODEs: Solvability, differential invariants, reduction of order, invariant solutions.

MA691 Linear and Nonlinear Waves

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	Clarkson Prof P

Contact Hours

36

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 demonstrate knowledge and critical understanding of the well-established principles within linear and nonlinear partial differential equations (PDEs);
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: Fourier transforms for linear differential equations, shock waves, exact solutions of nonlinear PDEs;
3 apply the concepts and principles in PDEs in well-defined contexts beyond those in which they were first studied, showing the ability to evaluate critically the appropriateness of different tools and techniques;
4 make appropriate use of MAPLE.

On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (Moodle);
7 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

M.J. Ablowitz, Nonlinear Dispersive Waves, Cambridge (2011)
J. Bellingham and A.C. King, Wave Motion, Cambridge (2000)
P.G. Drazin and R.S. Johnson, Solitons: an Introduction, Cambridge (1989)
R. Knobel, An Introduction to the Mathematical Theory of Waves, A.M.S. (2000)
J.D Logan, An Introduction to Partial Differential Equations, Wiley (1994)
I.N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill (1957)

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA588 (Mathematical Techniques & Differential Equations)
Co-requisite: None

For delivery to students completing Stage 1 from September 2016:
Pre-requisite: MAST5005 (Linear partial differential equations); MAST5012 (Ordinary differential equations)
Co-requisite: None

Synopsis *

Linear PDEs. Dispersion relations. Review of d'Alembert's solutions of the wave equation.
Quasi-linear first-order PDEs. Total differential equations. Integral curves and integrability conditions. The method of characteristics.
Shock waves. Discontinuous solutions. Breaking time. Rankine-Hugoniot jump condition. Shock waves. Rarefaction waves. Applications of shock waves, including traffic flow.
General first-order nonlinear PDEs. Charpit's method, Monge Cone, the complete integral.
Nonlinear PDEs. Burgers' equation; the Cole-Hopf transformation and exact solutions. Travelling wave and scaling solutions of nonlinear PDEs. Applications of travelling wave and scaling solutions to reaction-diffusion equations. Exact solutions of nonlinear PDEs. Applications of nonlinear waves, including to ocean waves (e.g. rogue waves, tsunamis).

MA692 Operators and Matrices

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Waterstraat Dr N

Contact Hours

36

Learning Outcomes

On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of matrix and operator theory;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of the material in the following areas: Hermitian matrices and their spectral properties, Hilbert spaces, linear operators and functionals, compact operators, spectral theory;
3 apply key aspects of operator theory in well-defined contexts, showing judgement in the selection and application of tools and techniques.

On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 communicate technical material competently;
7 demonstrate an increased level of skill in numeracy and computation;
8 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

J.R. Giles: Introduction to the Analysis of Normed Linear Spaces. Cambridge University Press (2000).
V.L. Hansen: Functional Analysis – Entering Hilbert Space. World Scientific (2006).
R. Horn , C. Johnson: Matrix Analysis. Cambridge University Press (1985).
C.D. Meyer: Matrix Analysis and Applied Linear Algebra. SIAM (2000).
B. Rynne, M. Youngson: Linear Functional Analysis. Springer (2008).
G. Strang: Linear Algebra and its Applications, 3rd edition. Saunders (1988).
N. Young: An Introduction to Hilbert space. Cambridge University Press (1988).
F. Zhang: Matrix Theory – Basic Results and Techniques. Springer (2011).

Pre-requisites

For delivery to students completing Stage 1 before September 2016:
Pre-requisite: MA552 (Analysis)
Co-requisite: None

For delivery to students completing Stage 1 after September 2016:
Pre-requisite: MAST5013 (Real Analysis 2)
Co-requisite: None

Synopsis *

Matrix theory: Hermitian and symmetric matrices, spaces of these matrices and the associated inner product, diagonalization, orthonormal basis of eigenvectors, spectral properties, positive definite matrices and their roots
Hilbert space theory: inner product spaces and Hilbert spaces, L^2 and l^2 spaces, orthogonality, bases, Gram-Schmidt procedure, dual space, Riesz representation theorem
Linear operators: the space of bounded linear operators with the operator norm, inverse and adjoint operators, Hermitian operators, infinite matrices, spectrum, compact operators, Hilbert-Schmidt operators, the spectral theorem for compact Hermitian operators.

MA7515 Discrete Mathematics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	Woodcock Dr C

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of the theory and practice of finite fields and their application to Latin squares, cryptography, m-sequences, cyclic codes and further error-correcting codes;
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: modular arithmetic, factorising polynomials, construction of finite fields, Latin squares, classical and public key ciphers including RSA, m-sequences, cyclic codes and further error correcting codes including BCH codes;
3 apply a range of concepts and principles of discrete mathematics in loosely defined contexts, showing good judgment in the selection and application of tools and techniques.

The intended generic learning outcomes:
On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed;
2 demonstrate a high level of capability in developing and evaluating logical arguments;
3 communicate arguments confidently with the effective and accurate conveyance of conclusions ;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make effective use of information technology skills such as online resources (Moodle), internet communication;
7 communicate technical material effectively;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

N L Biggs, Discrete Mathematics, Oxford University Press, 2nd edition, 2002
D Welsh, Codes and Cryptography, Oxford University Press, 1988
R Hill, A First Course in Coding Theory, Oxford University Press, 1980

Synopsis *

Discrete mathematics has found new applications in the encoding of information. Online banking requires the encoding of information to protect it from eavesdroppers. Digital television signals are subject to distortion by noise, so information must be encoded in a way that allows for the correction of this noise contamination. Different methods are used to encode information in these scenarios, but they are each based on results in abstract algebra. This module will provide a self-contained introduction to this general area of mathematics.
Syllabus: Modular arithmetic, polynomials and finite fields. Applications to
• orthogonal Latin squares,
• cryptography, including introduction to classical ciphers and public key ciphers such as RSA,
• "coin-tossing over a telephone",
• linear feedback shift registers and m-sequences,
• cyclic codes including Hamming,
In addition, for level 7 students: applications to further error-correcting codes including BCH codes.

MA7522 Integrable Systems

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	Wang Dr JP

Contact Hours

40

Learning Outcomes

The intended subject specific learning outcomes:
On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of integrable systems;
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: nonlinear differential equations, Hamiltonian systems, nonlinear difference equations;
3 apply a range of concepts and principles in integrable systems in various different contexts, showing good judgment in the selection and application of tools and techniques.

The intended generic learning outcomes:
On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed;
2 demonstrate a high level of capability in developing and evaluating logical arguments;
3 communicate arguments confidently with the effective and accurate conveyance of conclusions;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make effective use of information technology skills such as online resources (Moodle) and internet communication;
7 communicate technical material effectively;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

O. Babelon, D. Bernard and M. Talon, Introduction to Classical Integrable Systems, Cambridge Monographs on Mathematical Physics, Cambridge University Press, 2003.
M.J. Ablowitz and P.A. Clarkson, Solitons, Nonlinear Evolution Equations and Inverse Scattering, London Mathematical Society Lecture Note Series 149, Cambridge University Press, 1992.
P.G. Drazin and R.S. Johnson, Solitons: an introduction, Cambridge Texts in Applied Mathematics 2, Cambridge University Press, 1989.
J. Hietarinta, N. Joshi and F. W. Nijhoff, Discrete Systems and Integrability, Cambridge Texts in Applied Mathematics, Cambridge University Press, 2016.

Synopsis *

Integrable systems are special dynamical systems which can be solved exactly in some sense. They arise in a variety of settings, ranging from Hamiltonian systems and nonlinear wave equations to difference equations. This module covers the origins of the subject as well as modern topics like integrable maps and lattice equations.
- Liouville integrability in classical mechanics. Hamiltonian mechanics. Canonical symplectic form and Poisson brackets. Liouville's theorem (statement and examples). Lax pairs for finite-dimensional systems.
- Soliton equations. History and physical origins (e.g. Korteweg-de Vries and/or sine-Gordon). Conservation laws. Hamiltonian formalism. Lax pairs.
- Construction of solitons. Introduction to inverse scattering. Darboux-Bäcklund transformations. Hirota's method.
- Discrete integrability. Symplectic maps. Liouville's theorem (discrete version). Integrable lattice equations. Discrete Lax pairs with examples.
- Additional material for level 7 students (1 week). An extra topic in soliton theory/discrete integrability, such as: further inverse scattering, 3D consistency of lattice equations.

MA771 Applied Stochastic Modelling and Data Analysis

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Spring	H	15 (7.5)	90% Exam, 10% Coursework	
2	Canterbury	Spring	H	15 (7.5)	80% Exam, 20% Coursework	Ridout Prof M

Contact Hours

36

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the level 6 module students will be able to:
1 demonstrate systematic understanding of key aspects of computational statistics;
2 demonstrate the capability to deploy established approaches accurately to analyse and solve problems using a reasonable level of skill in calculation and manipulation of material in the following areas: numerical aspects of maximum likelihood estimation, EM algorithm and simulation methods;
3 apply key aspects of computational statistics in well-defined contexts, showing judgement in the selection and application of tools and techniques;
4 adapt R programs, showing judgement in the application of R.

The intended generic learning outcomes.
On successfully completing the level 6 module students will be able to:
1 manage their own learning and make use of appropriate resources;
2 understand logical arguments, identifying the assumptions made and the conclusions drawn;
3 communicate straightforward arguments and conclusions reasonably accurately and clearly;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make competent use of information technology skills such as online resources (moodle), internet communication;
7 communicate technical material competently;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Morgan, B. J. T. (2009) Applied stochastic modelling, Chapman and Hall.

Pre-requisites

MAST5001 (Applied Statistical Modelling 1); MAST5007 (Mathematical Statistics)

Synopsis *

Motivating examples; model fitting through maximum likelihood for specific examples; function optimization methods; profile likelihood; score tests; Wald tests; confidence interval construction; latent variable models; EM algorithm; mixture models; simulation methods; importance sampling; kernel density estimation; Monte Carlo inference; bootstrap; permutation tests; R programs.
In addition, for level 7 students: advanced EM algorithm methods, advanced simulation methods, writing R programs for advanced methods and applications.

MA772 Analysis of Variance

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	H	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Autumn	H	15 (7.5)	90% Exam, 10% Coursework	

Contact Hours

48, 36 lectures and 12 computer classes

Learning Outcomes

The Intended Subject Specific Learning Outcomes. On successful completion of the module students will have:
a. a reasonable knowledge of analysis of variance and its application to a
variety of different models.
b. a reasonable knowledge of the basic principles of experimental design.
c. a reasonable ability to do analysis of variance calculations with a computer, and to interpret the resulting output.
d. a reasonable understanding of the inter-relationship between the design of a study and its subsequent analysis.
e. some appreciation of the relevance experimental design and analysis to real world problems.

The Intended Generic Learning Outcomes. On successful completion of this module, students will have
a. developed their understanding of probability and statistics
b. applied a range of mathematical techniques to solve statistical problems.
c. developed their ability to abstract the essentials of problems and to formulate them mathematically.
d. improved their key skills in numeracy, written communication and problem solving
e. enhanced their study skills and ability to work with relatively little supervision.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

NR Draper and H Smith Applied Regression Analysis, Wiley, 3rd ed., 1998 (R)
AM Dean and D Voss Design and Analysis of Experiments, Springer, 1999 (B)
GM Clarke and RE Kempson Introduction to the Design and Analysis of Experiments, Arnold, 1997 (R)

Pre-requisites

Probability and Inference (MA629), Regression Models (MA632); Linear Algebra (MA553) is strongly recommended.

Synopsis *

Analysis of variance is a fundamentally important method for the statistical analysis of data. It is used widely in biological, medical, psychological, sociological and industrial research when we wish to compare more than two treatments at once. In analysing experimental data, the appropriate form of analysis of variance is determined by the design of the experiment, and we shall therefore discuss some aspects of experimental design in this module. Lectures are supplemented by computing classes which explore the analysis of variance facilities of the statistical package R. Syllabus: One-way ANOVA (fixed effects model); alternative models; least squares estimation; expectations of mean squares; distributional results; ANOVA table; follow-up analysis; multiple comparisons; least significant difference; confidence intervals; contrasts; orthogonal polynomials; checking assumptions; residual plots; Bartlett's test; transformations; one-way ANOVA (random effects model); types of experiment; experimental and observational units; treatment structure; randomisation; replication; blocking; the size of an experiment; two-way ANOVA; the randomised complete block design; two-way layout with interaction; the general linear model; matrix formulation; models of full rank; constraints; motivations for using least squares; properties of estimators; model partitions; extra sum of squares principle; orthogonality; multiple regression; polynomial regression; comparison of regression lines; analysis of covariance; balanced incomplete block designs; Latin square designs; Youden rectangles; factorial experiments; main effects and interactions.

MA776 Groups and Representations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	
1	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	Bowman Dr C

Contact Hours

42 hours of lectures and classes

Learning Outcomes

On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of the theory and practice of groups (with examples including permutation groups and matrix groups, and the combinatorics of the symmetric group), of linear algebra, and of representations and characters of groups.
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: calculations within permutation groups and matrix groups; computations of the character tables of small groups; derivation of structural information about a group from its character table; formulation and proof of simple statements about groups and representations in precise abstract algebraic language; breaking up representations into smaller simpler objects; composition series and composition factors of small groups.
3 apply a range of concepts and principles in group theory and representation theory in loosely defined contexts, showing good judgment in the selection and application of tools and techniques.

On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed
2 demonstrate a high level of capability in developing and evaluating logical arguments
3 communicate arguments confidently with the effective and accurate conveyance of conclusions
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working
5 solve problems relating to qualitative and quantitative information
6 make effective use of information technology skills such as online resources (moodle) and internet communication.
7 communicate technical material effectively
8 demonstrate an increased level of skill in numeracy and computation.
9 demonstrate the acquisition of the study skills needed for continuing professional development

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

We will not follow a single text, and the lecture notes will cover the entire syllabus. Nevertheless
G.D. James and M. Liebeck, Representations and characters of groups, CUP (2001)
J.P. Serre, Linear representations of finite groups, Springer GTM (1977)
J.L. Alperin and R.B. Bell, Groups and Representations, Springer GTM (1995)
contain a large amount of the material.

Pre-requisites

Pre-requisite: Students are expected to have studied introductory courses on linear algebra and groups.
Co-requisite: None

Synopsis *

Groups arise naturally in many areas of mathematics as well as in chemistry and physics. A concrete way to approach groups is by representing them as a group of matrices, in which explicit computations are easy. This approach has been very fruitful in developing our understanding of groups over the last century. It also helps students to understand aspects of their mathematical education in a broader context, in particular concepts from earlier modules (From Geometry to Algebra/Groups and Symmetries and Linear Algebra) have been amalgamated into more general and powerful tools.

This module will provide a rigorous introduction to the main ideas and notions of groups and representations. It will also have a strong computational strand: a large part of the module will be devoted to explicit computations of representations and character tables (a table of complex numbers associated to any finite group).

Syllabus:
1. Review of basic group theory (including matrix groups, the symmetric groups, permutation groups and symmetry groups, subgroups, conjugacy, normal subgroups and quotient groups, homomorphisms, group actions);
2. A concrete approach to groups via representations (including examples via group actions and the language modules);
3. Irreducible representations, Maschke's theorem, Schur's lemma;
4. Characters and their basic properties;
5. Character tables: theory and computations for small groups. Consequences.
In addition, for level 7 students:
6. Simple groups, composition series and the Jordan--Hölder theorem.

MA781 Practical Multivariate Analysis

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	H	15 (7.5)	70% Exam, 30% Coursework	
1	Canterbury	Spring	H	15 (7.5)	70% Exam, 30% Project	

Contact Hours

This module is organised in conjunction with the Multivariate Analysis (MA079) course which is a compulsory part of the MSc in Statistics. Students will attend about 18 lectures, with computer-based illustrations included as appropriate rather than treated separately. The remainder of the work will be arranged on an individual basis.

Learning Outcomes

The Intended Subject Specific Learning Outcomes. On successful completion of the module students
– will appreciate the range of multivariate techniques currently available,
– will be able to summarise and interpret multivariate data,
– will have a clear understanding of the logical link between multivariate techniques and corresponding univariate techniques, where appropriate,
– will be able to use multivariate techniques appropriately,
– will appreciate the opportunities for using statistical techniques of multivariate analysis to summarise and interpret complex sets of data,
– will be able to undertake standard multivariate hypothesis tests, and draw appropriate conclusions.

The Intended Generic Learning Outcomes. On successful completion of the module, students
– will have further developed a logical, mathematical approach to solving problems,
– will have enhanced their ability to work with relatively little guidance,
– will have gained further organisational and study skills.
On successful completion of the module, students will also have improved their key skills in written communication, numeracy, problem solving and information technology.

Method of Assessment

70% Examination, 30% Coursework

Preliminary Reading

KV Mardia, JE Kent and JM Bibby Multivariate Analysis, Academic Press, London, 1979
C Chatfield and AJ Collins Introduction to Multivariate Analysis, Chapman and Hall, 1980
DF Morrison Multivariate statistical methods, 4th ed., Duxbury, 2005

Pre-requisites

MA629, MA632

Synopsis *

This module considers statistical analysis when we observe multiple characteristics on an experimental unit. For example, a sample of students' marks on several exams or the genders, ages and blood pressures of a group of patients. We are particularly interested in understanding the relationships between the characteristics and differences between experimental units. Outline syllabus includes: measure of dependence, principal component analysis, factor analysis, canonical correlation analysis, hypothesis testing, discriminant analysis, clustering, scaling.

MA790 Symmetry Methods for Differential Equations

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	Mansfield Prof E

Contact Hours

40-42

Learning Outcomes

On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of techniques for finding and using Lie point symmetries to obtain exact solutions of given equations.
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: calculation of Lie point symmetry generators, canonical coordinates and differential invariants; identification of invariant solutions; successive reduction of order, where the Lie algebra is solvable; construction of the general solution of a given ordinary differential equation; advanced uses of Lie symmetries.
3 apply a range of concepts and principles in Lie symmetry methods in loosely defined contexts, showing good judgment in the selection and application of tools and techniques

On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed
2 demonstrate a high level of capability in developing and evaluating logical arguments
3 communicate arguments confidently with the effective and accurate conveyance of conclusions
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working
5 solve problems relating to qualitative and quantitative information
6 make effective use of information technology skills such as using online resources (Moodle).
7 extend their existing knowledge of mathematics into new areas through independent study
8 communicate technical material effectively
9 demonstrate an increased level of skill in numeracy and computation
10 demonstrate the acquisition of the study skills needed for continuing professional development

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

P. E. Hydon, Symmetry Methods for Differential Equations, Cambridge University Press, (2000).
H. Stephani, Differential Equations: Their Solution Using Symmetries, Cambridge University Press, (1989).
G. W. Bluman and S. C. Anco, Symmetry and Integration Methods for Differential Equations, Springer, (2002)

Pre-requisites

Pre-requisite modules: Students are expected to have studied material equivalent to that covered in the modules above.
Co-requisite modules: None

Synopsis *

Over a century ago, the Norwegian mathematician Sophus Lie made a simple but profound observation: each well-known method for solving a class of ordinary differential equations (ODEs) uses a change of variables that exploits symmetries of the class. Lie went on to develop this idea into a systematic method for attacking the problem of solving unknown differential equations. Essentially, one can use mathematical tools to force a given differential equation to reveal whether or not it has certain symmetries – provided it has, they can be used to simplify or solve the equation. This module is designed to enable students to understand the mathematics behind Lie's methods and to become proficient in using these powerful tools.
The following topics are covered.
Introduction: Symmetries of geometrical objects, symmetries of some first-order ODEs, solution via symmetries.
Lie symmetries of first-order ODEs: The infinitesimal generator, canonical coordinates, invariant points, Lie symmetries and standard solution methods.
How to find Lie symmetries: The linearized symmetry condition, solution of overdetermined systems, the Lie algebra of point symmetry generators.
Solution of higher-order ODEs: Solvability, differential invariants, reduction of order, invariant solutions.
In addition, for level 7 students:
Advanced topic: This will be selected from the following:
• Symmetry methods for PDEs.
• First integrals and dynamical symmetries.
• Discrete symmetries of ODEs
• Symmetries of difference equations.

MA791 Linear and Nonlinear Waves

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	Clarkson Prof P

Contact Hours

40-42

Learning Outcomes

On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of linear and nonlinear PDEs;
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: Fourier transforms for linear differential equations, shock waves, exact solutions of nonlinear PDEs;
3 apply a range of concepts and principles in PDEs in loosely defined contexts, showing good judgment in the selection and application of tools and techniques;
4 make effective and well-considered use of MAPLE.

On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed;
2 demonstrate a high level of capability in developing and evaluating logical arguments;
3 communicate arguments confidently with the effective and accurate conveyance of conclusions;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make effective use of information technology skills such as using online resources (Moodle);
7 demonstrate an increased level of skill in numeracy and computation.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

M.J. Ablowitz, Nonlinear Dispersive Waves, Cambridge (2011)
J. Bellingham and A.C. King, Wave Motion, Cambridge (2000)
P.G. Drazin and R.S. Johnson, Solitons: an Introduction, Cambridge (1989)
R. Knobel, An Introduction to the Mathematical Theory of Waves, A.M.S. (2000)
J.D Logan, An Introduction to Partial Differential Equations, Wiley (1994)
I.N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill (1957)

Pre-requisites

Pre-requisite: Students are expected to have studied material equivalent to that covered in the modules above.
Co-requisite: None

Synopsis *

Linear PDEs. Dispersion relations. Review of d'Alembert's solutions of the wave equation.
Quasi-linear first-order PDEs. Total differential equations. Integral curves and integrability conditions. The method of characteristics.
Shock waves. Discontinuous solutions. Breaking time. Rankine-Hugoniot jump condition. Shock waves. Rarefaction waves. Applications of shock waves, including traffic flow.
General first-order nonlinear PDEs. Charpit's method, Monge Cone, the complete integral.
Nonlinear PDEs. Burgers' equation; the Cole-Hopf transformation and exact solutions. Travelling wave and scaling solutions of nonlinear PDEs. Applications of travelling wave and scaling solutions to reaction-diffusion equations. Exact solutions of nonlinear PDEs. Applications of nonlinear waves, including to ocean waves (e.g. rogue waves, tsunamis).
Level 7 Students only. Further applications of shock waves and nonlinear waves.

MA792 Operators and Matrices

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	Waterstraat Dr N

Contact Hours

40-42

Learning Outcomes

On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of the theory of linear operators;
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: Hermitian matrices and their spectral properties, Hilbert spaces, linear operators and functionals, compact operators, spectral theory;
3 apply a range of concepts and principles in Hilbert space theory and operator theory in loosely defined contexts, showing good judgment in the selection and application of tools and techniques.

On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed;
2 demonstrate a high level of capability in developing and evaluating logical arguments;
3 communicate arguments confidently with the effective and accurate conveyance of conclusions;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 communicate technical material effectively;
7 demonstrate an increased level of skill in numeracy and computation;
8 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination and 20% coursework.

Preliminary Reading

J.R. Giles: Introduction to the Analysis of Normed Linear Spaces. Cambridge University Press (2000).
V.L. Hansen: Functional Analysis – Entering Hilbert Space. World Scientific (2006).
R. Horn , C. Johnson: Matrix Analysis. Cambridge University Press (1985).
C.D. Meyer: Matrix Analysis and Applied Linear Algebra. SIAM (2000).
B. Rynne, M. Youngson: Linear Functional Analysis. Springer (2008).
G. Strang: Linear Algebra and its Applications, 3rd edition. Saunders (1988).
N. Young: An Introduction to Hilbert space. Cambridge University Press (1988).
F. Zhang: Matrix Theory – Basic Results and Techniques. Springer (2011).

Pre-requisites

Pre-requisite: Students are expected to have studied material equivalent to that covered in the modules above.
Co-requisite: None

Synopsis *

Matrix theory: Hermitian and symmetric matrices, spaces of these matrices and the associated inner product, diagonalization, orthonormal basis of eigenvectors, spectral properties, positive definite matrices and their roots
Hilbert space theory: inner product spaces and Hilbert spaces, L^2 and l^2 spaces, orthogonality, bases, Gram-Schmidt procedure, dual space, Riesz representation theorem
Linear operators: the space of bounded linear operators with the operator norm, inverse and adjoint operators, Hermitian operators, infinite matrices, spectrum, compact operators, Hilbert-Schmidt operators, the spectral theorem for compact Hermitian operators.
Additional topics, especially for level 7 students may include:
- the Rayleigh quotient and variational characterisations of eigenvalues,
- the functional calculus,
- applications to Sturm-Liouville systems.

MA858 Computational Statistics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	Ridout Prof M

Contact Hours

32 hours of lectures and 8 terminal classes

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of the module, students will:
1. Have revised and integrated the main probability and statistical material of a standard undergraduate degree programme.
2. Have encountered a range of complex data.
3. Have an appreciation of probability models may be formulated for atypical data sets.
4. Have a good understanding of how likelihood-based classical procedures operate in practice.
5. Have experience of running a wide range of modern statistical procedures through running computer programs in MATLAB.

The intended generic learning outcomes
On successful completion of the module, students will:
1. Appreciate the importance of computing for modern statistical analysis.
2. Appreciate the breadth and importance of modern statistical methods.
3. Be able to describe a number of practical areas where statistical modelling is of importance.
4. Have enhanced their computer skills.
5. Have improved their ability to communicate effectively, and to work independently.
6. Have improved their skills in numeracy, problem solving, computing and written communication.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

B J T Morgan Applied Stochastic Modelling. (2nd ed., CRC Press) (E)
McCullagh, P. and Nelder, J. A. (1989) Generalized linear models, Chapman and Hall.

Synopsis *

This applied statistics module focusses on problems that occur in the fields of ecology, biology, genetics and psychology. Motivated by real examples, you will learn how to define and fit stochastic models to the data. In more complex situations this will mean using optimisation routines in MATLAB to obtain maximum likelihood estimates for the parameters. You will also learn how construct, fit and evaluate such stochastic models. Outline Syllabus includes: Function optimisation. Basic likelihood tools. Fundamental features of modelling. Model selection. The EM algorithm. Simulation techniques. Generalised linear models.

MA871		Asymptotics and Perturbation Methods				
Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
4	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48.

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module, H-level students will:

a) have developed a familiarity with the use of asymptotic techniques in the study of integrals and differential equations;
b) be able to obtain asymptotic approximations of various types of integrals;
c) be able to determine approximate solutions of linear differential equations;
d) be able to generate matched asymptotic expansions for singular perturbation and boundary layer problems
e) be able to use WKB (Wentzel-Kramers-Brillouin), multiple scales and related methods to obtain asymptotic expansions of solutions of some differential equations

In addition, M-level students will:
f) have a systematic understanding of the above topics;
g) be able to apply critically the techniques in complex situations.

The intended generic learning outcomes
On successful completion of this module, H -level students will have:
a) an enhanced ability to reason and deduce confidently from given definitions and constructions;
b) an enhanced understanding of what is meant by an answer to a modelling problem;
c) enhanced skills with mathematical and graphical software;
d) the ability to bring together several aspects of Mathematics - analytic, geometric and numerical ideas - as well as computation through the use of MAPLE.

On successful completion of this module, M-level students will also have:
e) an enhanced ability to read independently and manage their time

Method of Assessment

80% Examination, 20% coursework

Preliminary Reading

CM Bender and SA Orszag, Advanced Mathematical Methods for Scientists and Engineers I:
Asymptotic Methods and Perturbation Theory. (Springer-Verlag, New York, 1999) (E)

MJ Ablowitz and AS Fokas, Complex Variables: Introduction and Applications. (Cambridge University Press, Cambridge, 1997) (B)
EJ Hinch, Perturbation Methods. (Cambridge University Press, Cambridge, 1995) (B)
MH Holmes, Introduction to Perturbation Methods. (Springer-Verlag, New York, 1991) (B)
DS Jones, Introduction to Asymptotics. (World Scientific, Singapore, 1997) (B)
JD Logan, Applied Mathematics. (Second Edition, Wiley, New York, 1997) (B)
JA Murdock, Perturbations: Theory and Methods. (SIAM, Philadelphia, 1999) (B)
JD Murray, Asymptotic Analysis. (Springer-Verlag, New York, 1997) (R)

Pre-requisites

Synopsis *

The lectures will introduce students to asymptotic and perturbation methods for the approximate evaluation of integrals and to obtaining approximations for solutions of ordinary differential equations. These methods are widely used in the study of physically significant differential equations which arise in Applied Mathematics, Physics and Engineering. The material is chosen so as to demonstrate a range of mathematical techniques available and to illustrate some different applications which are amenable to such analysis.

• Asymptotics. Ordering symbols. Asymptotic sequences, expansions and series. Differentiation and integration of asymptotic expansions. Dominant balance. Solution of algebraic and transcendental equations.
• Asymptotic evaluation of integrals. Integration by parts. Laplace's method and Watson's lemma. Method of stationary phase.
• Approximate solution of linear differential equations. Classification of singular points. Local behaviour at irregular singular points. Asymptotic expansions in the complex plane. Stokes phenomena: Stokes and anti-Stokes lines, dominance and sub-dominance. Connections between sectors of validity. Airy functions.
• Matched asymptotic expansions. Regular and singular perturbation problems. Asymptotic matching. Boundary layer theory: inner, outer and intermediate expansions and limits. Uniform approximation.
• WKB method. Schrödinger equation and Sturm-Liouville problems. Turning points.
• Multiple scales analysis and related methods. Secular terms. Multiple scales method. Method of strained coordinates (Lindstedt-Poincaré method).

MA881 Probability and Classical Inference

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	
2	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	Ridout Prof M

Contact Hours

36 hours

Learning Outcomes

The intended subject specific learning outcomes and, as appropriate, their relationship to programme learning outcomes
On successful completion of this module, students will
1 have a systematic understanding of probability and statistical inference
2 be able to use a comprehensive range of relevant concepts and principles
3 be able to select and apply these to solve advanced problems in probability and statistical inference, using a variety of methods

The intended generic learning outcomes and, as appropriate, their relationship to programme learning outcomes

On successful completion of the module, students will
1 have developed a logical, mathematical approach to their work
2 have developed the ability to solve challenging problems

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Ross, S. (1994). A First Course in Probability, 4th Edition, New York: Prentice-Hall International.
Kendall, M.G. and Stuart, A. (1977-1983). The Advanced Theory of Statistics, 4th Edition, Volume 1 (Distribution Theory) and Volume 2 (Inference and Relationship), London: Griffin.
Casella, G. and Berger, R. L. (2002). Statistical Inference, 2nd Edition, Duxbury.
Feller, W. (1967). An Introduction to Probability Theory and its Application, John Wiley & Sons, Inc.

Synopsis *

This module begins by introducing probability, primarily as a tool that underlies the subsequent material on statistical inference. This includes, for example, various notions of convergence for random variables. Classical statistical inference assumes that data follow a probability model with some unknown parameters, and the main aims are to estimate these parameters and to test hypotheses about them. The focus of the module is to develop general methods of statistical inference that can be applied to a wide range of problems. Outline syllabus includes: probability axioms; marginal, joint and conditional distributions; Bayes theorem; important distributions; convergence of random variables; sampling distributions; likelihood; point estimation; interval estimation; likelihood-ratio, Wald and score tests; estimating equations.

MA883 Bayesian Statistics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	
2	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	Leisen Dr F

Contact Hours

36 hours

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of this module, students
- will be able to derive posterior distributions when analytically tractable;
- will understand how to derive posterior summaries, such as estimates, from the posterior distribution, including the predictive distribution;
- will be able to implement sampling based methods to Bayesian inference, such as the Gibbs sampler, when the posterior distribution is analytically intractable;
- will be able to undertake Bayesian decision theory and model choice;
- will understand the subjective and objective approaches to Bayesian inference.

The intended generic learning outcomes. On successful completion of this module, students
- will have further developed a logical, mathematical approach to solving problems;
- will have enhanced their ability to work with relatively little guidance;
- will have improved their key skills in written communication, numeracy and problem solving.

Method of Assessment

80% examination and 20% coursework

Preliminary Reading

A.F.M. Smith and Bernardo, J.M. (1994). Bayesian Theory. Wiley.
D. Gamerman and H.F. Lopes (2006). Markov Chain Monte Carlo: Stochastic Simulation for Bayesian Inference. 2nd Edition, Taylor and Francis.

Synopsis *

The origins of Bayesian inference lie in Bayes' Theorem for density functions; the likelihood function and the prior distribution combine to provide a posterior distribution which reflects beliefs about an unknown parameter based on the data and prior beliefs. Statistical inference is determined solely by the posterior distribution. So, for example, an estimate of the parameter could be the mean value of the posterior distribution. This module will provide a full description of Bayesian analysis and cover popular models, such as the normal distribution. Initially, the flavour will be one of describing the Bayesian counterparts to well known classical procedures such as hypothesis testing and confidence intervals. Current methods for inference involving posterior distributions typically involve sampling strategies. That is, due to the complicated nature of some posterior distributions, analytic methods fail to provide meaningful summaries. Hence, sampling from the posterior has become popular. A full description of sampling techniques, starting from rejection sampling, will be given. Outline Syllabus includes: Conjugate models (prior and posterior belong to the same family of parametric models). Predictive distributions; Bayes estimates; Sampling density functions; Gibbs and Metropolis-Hastings samplers; Winbugs; Bayesian regression and hierarchical models; Bayesian model choice; Decision theory; Objective priors; Exchangeability.

MA884 Principles of Data Collection

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn and Spring	M	15 (7.5)	80% Exam, 20% Coursework	Laurence Dr A

Contact Hours

40

Learning Outcomes

On successfully completing the level 7 module students will be able to:
1 demonstrate systematic understanding of sampling and experimental design;
2 demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: sampling, questionnaire design, analysis of variance, clinical trial design, advanced experimental design;
3 apply a range of concepts and principles in sampling and experimental design in loosely defined contexts, showing good judgment in the selection and application of tools and techniques;
4 make effective and well-considered use of R for the analysis of data from experiments.

On successfully completing the level 7 module students will be able to:
1 work competently and independently, be aware of their own strengths and understand when help is needed;
2 demonstrate a high level of capability in developing and evaluating logical arguments;
3 communicate arguments confidently with the effective and accurate conveyance of conclusions;
4 manage their time and use their organisational skills to plan and implement efficient and effective modes of working;
5 solve problems relating to qualitative and quantitative information;
6 make effective use of information technology skills such as R, online resources (moodle), internet communication;
7 communicate technical and non-technical material effectively;
8 demonstrate an increased level of skill in numeracy and computation;
9 demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% examination and 20% coursework

Preliminary Reading

Barnett, V. (2002) Sample Survey Principles and Methods. 3rd edition. New York, Wiley.
Cox, D.R. (1992) Planning of Experiments. New York, Wiley.
Cochran, W.G. & Cox, G.M. (1992) Experimental Designs. 2nd edition. New York, Wiley.
Cox. D.R & Reid, N. (2000) The Theory of the Design of Experiments. Boca Raton, Chapman & Hall/CRC
Lawson, J. (2015) Design and Analysis of Experiments with R. Boca Raton, Chapman & Hall/CRC.
Matthews, J. N. S. (2000) An Introduction to Randomized Controlled Clinical Trials. 2nd edition. Boca Raton, Chapman & Hall/CRC.

Synopsis *

Sampling: Simple random sampling. Sampling for proportions and percentages. Estimation of sample size. Stratified sampling. Systematic sampling. Ratio and regression estimates. Cluster sampling. Multi-stage sampling and design effect. Questionnaire design. Response bias and non-response.
General principles of experimental design: blocking, randomization, replication. One-way ANOVA. Two-way ANOVA. Orthogonal and non-orthogonal designs. Factorial designs: confounding, fractional replication. Analysis of covariance.
Design of clinical trials: blinding, placebos, eligibility, ethics, data monitoring and interim analysis. Good clinical practice, the statistical analysis plan, the protocol. Equivalence and noninferiority. Sample size. Phase I, II, III and IV trials. Parallel group trials. Multicentre trials.
In addition, level 7 students will study hierarchical designs: fixed and random effects models; split-plot designs; crossover trials; variance components.

MA888 Stochastic Models in Ecology and Medicine

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

30 lectures, 3 classes

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of this module, students
- will have met a wide range of ecological and medical data sets, and understood how models may be derived for them;
- will have developed the skill of applying modern statistical techniques applicable to ecology and medicine;
- will have experience of modern statistical methods that make use of the power of modern computers, using RMARK and WinBUGS;
- will understand the use of stochastic modelling and the probabilistic concepts involved;

The intended generic learning outcomes. On successful completion of the module, students
- will have an appreciation of the originality required for problem solving, linked to research work taking place at the University of Kent;
- will have experience of the application of scientific computing to solve substantive real world problems;

Method of Assessment

80% examination and 20% coursework

Preliminary Reading

Collett. D. (2003) Modelling Survival Data in Medical Research, Second Edition. Chapman & Hall/CRC, Boca Raton.
Williams, B.K., Nichols, J.D. and Conroy, M.J. (2001) Analysis and Management of Animal Populations. Academic Press, San Diego.
Amstrup, S.C., McDonald, T.L. and Manly, B.F.J. (2005) Handbook of capture-recapture analysis. Princeton University Press.
McCrea, R.S. and Morgan, B.J.T. (2014) Analysis of capture-recapture data. Chapman and hall.CRC Press, Boca Raton.

Synopsis *

This module considers the development and application of stochastic models in two specific areas. The ecological part is focused on the analysis of data collected on wild animals. Particular attention will be given to estimating how long wild animals live, and also to estimating the sizes of mobile animal populations. The medical part also considers the estimation of survival, but in this case for human beings, with less data loss due to individuals leaving the study than is typical in ecological studies. In survival data it is often known only that individuals survived for a certain period of time, with exact survival time being unknown. This is called censoring and its implications will be discussed in detail. Outline Syllabus includes: Estimating abundance; estimating survival; using covariates; multi-state models; parameter redundancy; human survival data with censoring; the hazard and related functions; parametric and semiparametric survival models.

MA889 Analysis of Large Data Sets

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	
2	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

36 hours

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of the module students
- will be able to summarise and interpret multivariate data effectively;
- will have a critical awareness of the logical link between multivariate techniques and corresponding univariate techniques;
- will have a systematic understanding of a wide range of modern techniques in dimension reduction, regarding to their strengths and weakness;
- will be able to use statistical software to apply multivariate techniques and variable selection methods;
- will be able to select and apply these solve practical problems, to undertake statistical calculations and manipulations, and to communicate the results effectively to statisticians.

The intended generic learning outcomes. On successful completion of the module students
- will have developed mathematical, critical approach to their work;
- will have developed the ability to solve practical problems.
- will have improved their key skills in numeracy, problem solving and information technology.

Method of Assessment

80% examination and 20% coursework

Preliminary Reading

K. V. Mardia, J. T. Kent, and J. M. Bibby (1979) Multivariate analysis, London, Academic Press
D. F. Morrison (1990) Multivariate Statistical Method, McGraw-Hill Series in Probability and Statistics.
T. Hastie, R. Tibshirani and J. H. Friedman (2009) The Elements of Statistical Learning, Springer-Verlag.
P. J. Brown (1994) Measurement, Regression and Calibration, Oxford University Press

Synopsis *

This module considers statistical analysis when we observe multiple characteristics on an experimental unit. For example, a sample of students' marks on several exams or the genders, ages and blood pressures of a group of patients. We are particularly interested in understanding the relationships between the characteristics and differences between experimental units. Regression methods can be used if one characteristic can be treated as a response variable and the others as explanatory variables. Variable selection on the explanatory variables can be daunting if the number of characteristics is large and suitable methods will be investigated. Outline Syllabus includes: measure of dependence, principal component analysis, factor analysis, canonical correlation analysis, hypothesis testing, discriminant analysis, clustering, scaling, information criterion methods for variable selection, false discovery rate, penalised maximum likelihood.

MA962 Geometric Integration

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn and Spring	M	15 (7.5)	70% Exam, 15% Coursework, 15% Project	Krusch Dr S

Contact Hours

30 hours

Learning Outcomes

On successful completion of this module students will have increased their knowledge, understanding, intuition and computational expertise in:

(i) numerical methods and their properties;
(ii) geometric interpretation of differential equations and numerical algorithms;
(iii) the meaning and interpretation of error in approximations, in particular the relative importance of local errors versus global properties;
(iv) the importance, meaning and interpretation of numerical stability;
(v) specific sophisticated numerical tools which preserve certain mathematical structures;
(vi) proficient use of mathematical software such as MatLab to masters level.

We expect students successfully completing the module to have:

(i) an enhanced ability to reason and deduce confidently from given definitions and constructions;
(ii) an enhanced understanding of what is meant by an answer to a modelling problem;
(iii) an enhanced ability to read independently and manage their time;
(iv) enhanced skills with mathematical and graphical software, to postgraduate level.

On completion of the module students will have:

(v) matured in their problem formulating and solving skills;
(vi) consolidated a wide variety of Calculus, Linear Algebra, Mathematical Modelling, and Mathematical Methods based skills.

Method of Assessment

70% Examination, 15% Coursework, 15% Project

Preliminary Reading

All texts are available in the Templeman library and are recommended for background reading.
Books:
Simulating Hamiltonian Dynamics, Leimkuhler and Reich, Cambridge University Press, 2005.
Geometric Numerical Integration, Hairer and Lubich and Wanner, second edition, Springer Verlag, 2006.
Review articles:
Six Lectures in Geometric Integration, MacLachlan and Quispel, in Foundations of Computational Mathematics pages 155-210, ed. R. DeVore, A. Iserles, E. S¨uli, Cambridge University
Press, Cambridge, 2001. (Available online)
Geometric Integration and its Applications, Handbook of Numerical Analysis, Volume XI NorthHolland 2000.

Pre-requisites

MA587 is highly recommended as a pre-requisite. Otherwise MA587 is a co-requisite.

Synopsis *

The equations studied in this module will be ordinary differential systems, especially Hamiltonian systems. The aim of this subject area is to obtain and study numerical solutions of these systems that preserve specific qualitative and geometric properties. For certain differential equations, these geometric methods can be far superior to standard numerical methods. The syllabus includes: A review of basic numerical methods, variational methods and Hamiltonian mechanics; Properties that numerical methods can preserve (first integrals, symplecticity, time reversibility); Geometric numerical methods (modified Euler and Runge-Kutta methods, splitting methods); Use and misuse of the various notions of error.

MA963 Poisson Algebras and Combinatorics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn and Spring	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours
up to 30 hours

Learning Outcomes
The intended subject specific learning outcomes. Students who successfully complete this module will
(a) have a sound knowledge of the basic structure of Poisson algebras and their quantisations
and be familiar with examples including quantum affine spaces and quantum matrices;
(b) be able to compute symplectic leaves of Poisson algebras;
(c) have increased their knowledge of the theory of symmetric groups;
(d) have increased their knowledge of the theory and practice of matrices and linear algebra;
(e) have learned how to formulate and prove statements about Poisson algebras in precise abstract algebraic language;
(f) have a sound knowledge of combinatorial objects such as Cauchon diagrams, pipe dreams, planar networks.

The intended generic learning outcomes. On completion of the module students will
(a) have matured in their problem formulating and solving skills;
(b) have an enhanced capacity to communicate mathematical statements and conclusions;
(c) better be able to appreciate mathematics as a unified discipline;
(d) consolidated a wide variety of Calculus, Linear Algebra, Geometry, Combinatorics, and Mathematical Methods based skills;
(e) appreciate the power of algorithmic methods in Algebra/Combinatorics/Geometry.

Method of Assessment
80% examination and 20% coursework.

Preliminary Reading
We will not follow a single text, and the lecture notes will cover the entire syllabus. Nevertheless the following books contain a large amount of the material.
KA Brown & KR Goodearl, Lectures on Algebraic Qantum Groups. (Advanced Courses in Mathematics. CRM Barcelona, Birkhäuser Verlag, Basel, 2002) (B)

FR Gantmacher, The theory of matrices. Vol. 1. (AMS Chelsea Publishing, Providence, RI, 1998) (B)
S Launois & TH Lenagan, From quantum algebras to total non-negativity. (available at www.kent.ac.uk/ims/personal/sl261/Teaching/LTCC2009/LTCC2009.pdf) (R)

P Vanhaecke, Integrable Systems in the realm of Algebraic Geometry. (Lecture Notes in Mathematics 1638, Springer-Verlag, 2001) (B)

Pre-requisites
None

Synopsis *
The general topics of this module are Poisson algebras, their quantisations, and applications to combinatorics.
Poisson algebras first appeared in the work of Siméon-Denis Poisson two centuries ago when he was studying the three-body problem in celestial mechanics. Since then, Poisson algebras have been shown to be connected to many areas of mathematics and physics.

This module will provide a rigorous but example led introduction to the main ideas and notions of Poisson algebras and their quantisations. Specific applications will be to problems in combinatorics and to the study of totally positive matrices that are used in statistics, game theory, mathematical economics, mathematical biology.... This module will have a strong computational strand: a large part of the module will be devoted to explicit computations of symplectic leaves of Poisson algebras and to algorithmic methods in total positivity.

The syllabus will be
• Poisson algebras: basic structure and examples. Symplectic leaves;
• Symplectic leaves in Poisson matrix varieties and Bruhat order on the symmetric group;
• Deformation of Poisson algebras: an introduction to algebraic quantum groups and their prime ideals through examples (quantum plane, quantum matrices...);
• Totally positive/nonnegative matrices: definition, examples, properties and cell decomposition.
• Link between total positivity and Poisson algebras;
• Algorithmic methods for detection of totally nonnegative matrices.

The curriculum can be extended in various ways: Poisson-Lie groups, Coxeter groups, Hopf algebras, representation theory, and these are suitable for project work.

MA964 Applied Algebraic Topology

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Spring	M	15 (7.5)	70% Exam, 15% Coursework, 15% Project	Shank Dr RJ

Contact Hours

24-36

Learning Outcomes

The Intended Subject Specific Learning Outcomes. Students who have successfully completed this module will:
(a) understand the basic concepts of topology with particular emphasis on cw complexes, manifolds and simplicial complexes;
(b) be able to apply topological methods to real-world problems;
(c) be able to use homological and computational methods to solve topological problems;
(d) have an improved geometric and algebraic intuition;
(e) have an enhanced ability to formulate and prove abstract mathematical statements, and
appreciate their connection with concrete calculation;
(f) have enhanced their computational skills.

The Intended Generic Learning Outcomes. We expect students successfully completing the module to have:
(a) an enhanced ability to communicate their own ideas clearly and coherently;
(b) an enhanced ability to read and comprehend mathematical ideas;
(c) matured in their problem solving skills;
(d) a greater appreciation of abstract concepts;
(e) consolidated their grasp of a wide variety of mathematical techniques and methods.

Method of Assessment

70% Examination, 15% Coursework, 15% Project

Preliminary Reading

MA Armstrong, Basic Topology. (Springer, 1983) (E)
Kaczynski, Mischaikow & Mrozek, Computational Homology. (Springer, 2004) (R)
Ghrist, Bar codes: The persistent topology of data. (Bulletin of the AMS, vol 45, no 1 (2008) 61–75) (B)
WS Massey, A Basic Course in Algebraic Topology. (Springer, 1991) (R)
de Silva & Ghrist, Homological Sensor Networks. (Notices of the AMS, vol 54, no 1, 2007 10–17) (B)
WA Sutherland, Introduction to Metric & Topological Spaces. (2nd edition, Oxford UP, 2009) (R)

Pre-requisites

MA567 Topology

Synopsis *

There is growing interest in applying the methods of algebraic topology to data analysis, sensor networks, robotics, etc. The module will develop the necessary elements of algebra and topology, and investigate how these techniques are used in various applications. The syllabus will include: an introduction to manifolds, CW complexes and simplicial complexes; an investigation of the elements of homotopy theory; an exploration of homological and computational methods; applications such as homological sensor networks and topological data analysis.

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor

Contact Hours

42-48 hours

Learning Outcomes

The Intended Subject Specific Learning Outcomes. On successful completion of this module students will have increased their knowledge, understanding, intuition and computational expertise in:
(a) rigorous thinking
(b) detecting symmetries and common patterns
(c) systematic observation, generalization and techniques of proof
(d) using group theory to calculate with symmetries
(e) distinction and classification of objects up to equivalences and symmetries
(f) the use of \normal forms" and \invariants" to distinguish symmetry classes
(g) combinatorial analysis and enumeration of symmetry classes and group orbits
(h) proficient use of mathematical software such as Maple and MAGMA to masters level

The Intended Generic Learning Outcomes. We expect students successfully completing the module to have
(i) an enhanced ability to correctly formulate classification problems and solve them efficiently;
(ii) enhanced skills in understanding and communicating mathematical results and conclusions;
(iii) a holistic view of mathematics as a problem solving and intellectually stimulating discipline;
(iv) an appreciation of algorithms and computational methods in algebra and group theory.

On completion of the module students will have:
_ matured in their problem formulating and solving skills;
_ consolidated a variety of tools from abstract algebra to model and classify concrete objects and configurations.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

G Burde & H Zieschang, Knots. (De Gruyter Studies in Mathematics, 1985, Walter de Gruyter, ISBN 3-11-008675-1)

LH Kauffman, On Knots. (Princeton, 1987, ISBN 0-691-08435-1)
A Kerber, Applied finite group actions. (Springer, 1999, ISBN/ISSN 3540659412)
WBR Lickorish, An introduction to knot theory. (Springer, 1997, ISBN/ISSN 038798254X)
V Manturov, Knot Theory. (Chapman & Hall, 2004, ISBN 1-415-31001-6)
K Murasugi, Knot theory and its applications. (Birkhäuser, 1996, ISBN/ISSN 0817638172)

Pre-requisites

MA565

Synopsis *

In this module we will study certain configurations with symmetries as they arise in real world applications. Examples include knots described by "admissible diagrams" or chemical structures described by "colouring patterns". Different diagrams and patterns can describe essentially the same structure, so the problem of classification up to equivalence arises. This will be solved by attaching "invariants" which are then put in "normal form" to distinguish them. The syllabus will be as follows: (a) Review of basic methods from linear algebra, group theory and discrete mathematics; (b) Permutation groups, transitivity, primitivity, Burnside formula; (c) Finitely generated Abelian groups; (d) Applications to knot theory, Reidemeister moves, the Abelian knot group; (e) Examples, observations, generalizations and proofs; (f) General Polya-enumeration (as an extension of the Burnside formula).

MA967 Quantum Mechanics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
3	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	Dunning Dr C

Contact Hours

40-42

Learning Outcomes

The intended subject specific learning outcomes.
On successfully completing the level 7 module students will be able to:
1, demonstrate systematic understanding of introductory quantum theory
2. demonstrate the capability to solve complex problems using a very good level of skill in calculation and manipulation of the material in the following areas: potential wells and barriers in one dimension, the treatment of eigenvalue problems in quantum mechanics and the hydrogen atom.
3. apply a range of concepts and principles in quantum mechanics in loosely defined contexts, showing good judgement in the selection and application of tools and techniques.

The intended generic learning outcomes.
On successfully completing the level 7 module students will be able to:
1. work competently and independently, be aware of their own strengths and understand when help is needed
2. demonstrate a high level of capability in developing and evaluating logical arguments
3. communicate arguments confidently with the effective and accurate conveyance of conclusions
4. manage their time and use their organisational skills to plan and implement efficient and effective modes of working
5. solve problems relating to qualitative and quantitative information
6. communicate technical material effectively
7. demonstrate an increased level of skill in numeracy and computation
8. demonstrate the acquisition of the study skills needed for continuing professional development.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

FW Byron, Mathematics of classical and quantum physics. (Addison-Wesley, 1970) (B)
A Durrant, Quantum Physics of Matter. (Institute of Physics 2000) (B)
J Manners, Quantum Physics: An introduction. (Institute of Physics, 2000) (B)
MA Nielsen & IL Chuang, Quantum Computation and Quantum Information. (Cambridge University Press, 2001) (B)

AIM Rae, Quantum Physics: A Beginner's Guide. (Oneworld Publications, 2005) (B)
JJ Sakurai, Modern quantum mechanics. (Addison-Wesley, 1994) (B)
R Shankar, Principles of quantum mechanics. (Plenum Press, 1994) (B)
K Hannabuss, An introduction to quantum theory. (Oxford University Press, 1997) (B)

Pre-requisites

None.

Synopsis *

Quantum mechanics provides an accurate description of nature on a subatomic scale, where the standard rules of classical mechanics fail. It is an essential component of modern technology and has a wide range of fascinating applications. This module introduces some of the key concepts of quantum mechanics from a mathematical point of view. Outline syllabus: why classical mechanics fails; the Schrödinger equation and interpretation of the wavefunction; applications of quantum mechanics.

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor

Contact Hours

24-36

Learning Outcomes

Learning Outcomes
On successful completion of the module, students will have an understanding of two significant and substantial areas of applied mathematics, namely the wave equation and digital processing, together with their applications to acoustics and to music recording.
Students who have successfully completed this module will:
· Understand a range of basic concepts used to model and process sound waves and digital signals · Have a reasonable ability to perform basic computational skills:
calculations with Bessel functions, Discrete Fourier transforms, convolutions, sampling, and filtering · Have a reasonable knowledge, and understand the place in the theory:
solution methods of the wave equation in square and circular domains, properties of Bessel functions and their role in the Fourier series of modulated sin waves, discrete analogues of the Fourier transform and convolution · Be exposed to more advanced material such the Gabor transform which allows musical signals to be analysed mathematically, as well as the rich variety of other methods used to analyse music, such as the geometry of musical rhythms and chord spaces · Gain experience and solve problems using the analytic skills developed, within the application to sound, and understand their relevance to modelling, and digital processing of music · Be aware of, and have the opportunity to perform: relevant computer calculations and graphics such as animations of vibrating drums; sampled, filtered and modulated signals; and spectrograms.

Method of Assessment

70% Examination, 15% Coursework, 15% Project

Preliminary Reading

D. Benson, Music: A Mathematical Offering, Cambridge University Press, 2006 G. Loy, Musimathics: The Mathematical Foundations of Music MIT Press, 2007 S.W. Smith, Digital Signal Processing, Newnes, 2003.
N Collins, Introduction to Computer Music. (Wiley, 2010) (B)
D. Tymoczko, A Geometry of Music Oxford University Press, 2011.
G. Toussaint, The Geometry of Musical Rhythm CRC Press, 2013.
Papers:
GW Don, KK Muir, GB Volk and JS Walker, Music: Broken Symmetry, Geometry and Complexity, Notices of the American Mathematics Society 57 (1) pp 30--49

Pre-requisites

None

Synopsis *

This module is divided into two - one part is about the mathematics of sound both acoustic and digital, and the other is about the structure of music as it affects musical composition. The mathematics of sound includes the study of the linear wave equation, in particular, the mathematics of drums and Chladni patterns. We then move on the mathematics of digital sound - the discrete Fourier transform, the short time Fourier transform and the Gabor transform. Here we can answer questions like, does Louis Armstrong play the trumpet the same way he sings? And, how to slow down music without losing pitch? The mathematics of rhythm and harmony are two very different fields of study. Many world music rhythms can be studied using the Euclidean algorithm, and we will also take a look at the theory of rhythmic tilings which underpin cannons and more modern compositions. Finally, the harmonic progression of a musical composition can be modelled as a path in chord space. In this part of the module, we will look at how simple geometric ideas are used to model voice leading and harmony. For this last part, familiarity with the keyboard would be helpful but is not a pre-requisite.

MA969 Applied Differential Geometry

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48 hours.

Learning Outcomes

The Intended Subject Specific Learning Outcomes. On successful completion of this module students will:
(i) understand basic geometric objects such as curves and surfaces and be able to determine their intrinsic properties
(ii) be able to derive the geometric evolution equations for curves and surfaces and understand the connection with nonlinear integrable systems
(iii) have broadened their experience with the basic concepts in Riemannian geometry such as metrics, connections and curvatures
(iv) have developed awareness of modern applications to mathematical physics, computer vision and image processing

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

R Hartley & A Zisserman, Multiple View geometry in computer vision. (Cambridge university press, 2nd ed, 2003) (B)

R Kimmel, Numerical geometry of images, theory, algorithms and applications. (Springer Verlag, 2003) (B)

PJ Olver, Lectures on moving frames. (preprint, University of Minnesota, 2008) (B)
C Rogers & WK Schief, Bäcklund and Darboux transformations: Geometry and modern applications in soliton theory. (Cambridge University Press, 2002) (B)

IA Taimanov, Lecture on differential geometry. (EMS series of Lectures in Mathematics, 2008) (R)

Pre-requisites

None.

Synopsis *

Differential geometry studies geometrical objects using analytical methods. It originates in classical mechanics. Modern differential geometry has made a huge impact in the development of nonlinear mathematical physics including integrable systems and string theory. Nowadays differential geometry is at the centre of the analysis of pattern recognition, image processing and computer graphics.

Indicative specific subtopics are:
• Theory of curves. Plane and space curves. Euclidean invariants of curves. Frenet frame.
• Theory of surfaces. Metrics on regular surface. Curvature of a curve on a surface. Gaussian curvature and mean curvature. Covariant derivative and geodesics. The Euler-Lagrange equations. Minimal surfaces.
• Evolution of curves and surfaces as integrable systems: Invariant curve evolution. The mean curvature flows. The connection with integrable systems. The modified Korteweg de-Vries equation.
• Curves in Riemannian manifolds: Riemannian metrics, connections, curvatures and geodesics. Curves evolution in Riemannian manifold with constant curvature.
• Modern applications.
i. 2D and 3D projective geometry and application to multiple view geometry in computer vision;
ii. Moving frames, invariant signatures in pattern recognition;
iii. Poisson manifold and Hamiltonian systems.

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor

Contact Hours

42-48 lectures and example classes

Learning Outcomes

The intended subject specific learning outcomes. On successful completion of this module students will:
a) be able to work with fundamental concepts in functional analysis, such as linear operators and functionals;
b) have a grasp of formal definitions and rigorous proofs in analysis;
c) have gained an appreciation of a wider context in which previously encountered concepts from analysis, such as convergence and continuity, can be used;
d) be able to apply abstract ideas to concrete problems in analysis;
e) appreciate differences between analysis in infinite and finite dimensional spaces;
f) be aware of applications of basic techniques and theorems of functional analysis in other areas of mathematics, e.g., approximation theory, and the theory of ordinary differential equations.
In addition M-level students will have
g) an increased ability to understand on their own, and communicate to others, fundamental ideas and results in abstract mathematical analysis

The intended generic learning outcomes. We expect students successfully completing the module to have
a) an enhanced ability to correctly formulate abstract problems and solve them efficiently;
b) enhanced skills in understanding and communicating mathematical results and conclusions;
c) furthered a holistic view of mathematics as a problem solving and intellectually stimulating discipline;
d) an appreciation of the power of abstract reasoning and formal proofs in mathematics and its applications
On successful completion of this module, M-level students will also have:
e) an enhanced ability for independent learning.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

Introductory Functional Analysis with Applications, Erwin Kreyszig, John Wiley, 1978.
Principles of Mathematical Analysis. Walter Rudin, International Series in Pure and Applied Mathematics, McGraw-Hill, 1976 3rd edition.
Beginning Functional Analysis, Karen Saxe, Springer, 2002.
Introduction to Functional Analysis, Angus E.Taylor, David C.Lay, John Wiley, 1980 2nd edition.
Functional Analysis. Walter Rudin. McGraw-Hill, 1991 2nd edition.

Pre-requisites

None

Synopsis *

This module will give an introduction to one of the main areas underpinning research in Analysis today: Functional Analysis, which has applications in many sciences, in particular in the modern theory of solutions of partial differential equations. As well as giving the main definitions and theorems in the area, the module will focus on applications, in particular to differential equations and in approximation theory. The following topics will be covered in the module: 1) Linear spaces: Normed and Banach spaces, Inner-product and Hilbert spaces, examples 2) Linear operators and functionals: bounded linear operators, functionals, dual spaces, reflexive spaces, adjoint operators, selfadjoint operators, examples 3) Fundamental theorems: Hahn-Banach, Uniform boundedness principle, Open mapping & Closed graph theorem, Baire Category theorem 4) Fixed point theorems and applications to differential and integral equations 5) Applications in approximation theory: best approximation in Hilbert space, approximation of continuous functions by polynomials. Possible additional topic: Spectral theory of bounded linear operators, weak and weak* topologies, algebras of bounded linear operators.

MA972 Algebraic Curves in Nature

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn and Spring	M	15 (7.5)	70% Exam, 30% Coursework	Hone Prof A

Contact Hours

30 hours

Learning Outcomes

The Intended Subject Specific Learning Outcomes. To increase students' knowledge, understanding, intuition and computational expertise in:
(a) rigorous thinking
(b) calculating with and visualization of geometrical objects
(c) systematic observation, generalization and techniques of proof
(d) the use of geometrical methods in other areas of mathematics and physics
(e) algebraic and analytical techniques for understanding geometry
(f) classification of objects according to their topological and geometrical properties
(g) connecting abstract mathematics to the real world
(h) proficient use of mathematical software such as Maple and MAGMA to masters level

The Intended Generic Learning Outcomes. We expect students successfully completing the module to have
(i) an enhanced ability to correctly formulate geometrical problems and solve them efficiently;
(ii) enhanced skills in understanding and communicating mathematical results and conclusions;
(iii) a holistic view of mathematics as a problem solving and intellectually stimulating discipline;
(iv) an appreciation of algorithms and computational methods in geometry.
On completion of the module students will have:
- matured in their problem formulating and solving skills;
- consolidated a variety of analytical and algebraic tools to model and classify geometrical objects and configurations.

Method of Assessment

70% examination, 30% coursework

Preliminary Reading

JWS Cassels, Lectures on elliptic curves. (LMS Student Texts 24, Cambridge, 1991, ISBN-10 0521425301) (B)

F Kirwan, Complex Algebraic Curves. (LMS Student Texts 23, Cambridge, 1992, ISBN-10 0521423538) (B)
N Koblitz, Algebraic Aspects of Cryptography. (Springer, 1998, ISBN 978-3-540-63446-1) (B)
R Miranda, Algebraic Curves and Riemann Surfaces. (Graduate Studies in Math., vol. 5, AMS, 1995, ISBN 0-8218-0268-2) (B

JH Silverman, The Arithmetic of Elliptic Curves. (Graduate Texts in Mathematics 106, Springer, 1986, ISBN 0-387-96203-4) (B)

ET Whittaker & GN Watson, A Course of Modern Analysis. (Cambridge, fourth edition, 1927 (reprinted 2005), ISBN 0-521-58807-3) (B)

Pre-requisites

None.

Synopsis *

In this module we will study plane algebraic curves and the way that they arise in applications to other parts of mathematics and physics. Examples include the use of elliptic functions to solve problems in mechanics (e.g. the pendulum, or Euler's equations for rigid body motion), spectral curves of separable Hamiltonian systems, and algebraic curves over finite fields that are used in cryptography. The geometrical properties of a curve are not altered by coordinate transformations, so it is important to identify quantities that are invariant under such transformations. For curves, the most basic invariant is the genus, which is most easily understood in terms of the topology of the associated Riemann surface: it counts the number of handles or “holes”. The case of genus zero (corresponding to the Riemann sphere) is well understood, but curves of genus one (also known as elliptic curves) lead to some of the most interesting and difficult problems in modern number theory.

• Review of basic results from complex analysis and topology;
• Riemann surfaces and plane curves in complex affine and projective space;
• The genus of a curve: degree-genus and Riemann-Hurwitz formulae;
• Genus one: elliptic curves and their group structure; elliptic functions and elliptic integrals, with applications;
• Higher genus: functions, divisors and differentials on algebraic curves; Riemann-Roch theorem; example: hyperelliptic curves.

MA973 Basic Differential Algebra

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Spring	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

28 (if lectured)

Learning Outcomes

The intended subject specific learning outcomes and, as appropriate, their relationship to programme learning outcomes
On successful completion of this module students will:
a) be familiar with basic structures of differential algebra and the ideal/variety correspondence for nonlinear differential systems;
b) be able to simplify and normalize small examples of differential systems and use dedicated computer algebra packages for big ones;
c) be able to separate the generic solution from singular components by way of differential reduction in nonlinear models;
d) be able to write small Maple scripts using the differential algebra functions from the existing Maple library;
e) have strengthened their basic knowledge in commutative algebra and algebraic geometry, viewing also differential objects from an algebraic perspective;
f) have learned how to prove some statements in differential algebra in terms of ideals and reduction;
g) have some knowledge of characteristic sets as an analog of Groebner bases, with skills for computing them manually or by dedicated packages;
h) handle the main tools provided in the Maple package "DifferentialAlgebra" and be able to apply them for various tasks on concrete problems.
The intended generic learning outcomes and, as appropriate, their relationship to programme learning outcomes
On successful completion of the module students will have improved their:
a) skill of specifying problems, solving them algorithmically as much as possible;
b) skill of communicating mathematical statements and conclusions;
c) vision of mathematics as a unified field with powerful analogies;
d) understanding of the complementary nature of analytic / algebraic thinking;
e) appreciation of algorithmic tools for solving mathematical problems;

Method of Assessment

80% examination, 20% coursework

Preliminary Reading

Since the discipline of differential algebra is rather young, there is no suitable textbook on differential algebra, so there will be specific lecture notes for this module, complemented by reading assignments for appropriate passages in the following reference works:

(1) Joseph Fels Ritt, Differential Algebra, Dover Publications, New York, 1966.

(2) Ellis Kolchin, Differential Algebra & Algebraic Groups, Academic Press, NY, 1973.

(3) Andy Magid, Lectures on Differential Galois Theory, 2nd ed., AMS, 1994.

(4) Irving Kaplansky, An Introduction to Differential Algebra, Hermann, Paris, 1957.

(5) Kolchin Seminar in Differential Algebra, http://www.sci.ccny.cuny.edu/~ksda .

The website (5) is a particularly nice starting point for exploring a rich variety of different topics in differential algebra, both elementary and advanced.

Pre-requisites

Polynomials in Several Variables (MA574), or other courses on commutative algebra

Synopsis *

Differential algebra is a relatively recent branch of algebra that exploits the analogies between systems of algebraic equations and nonlinear systems of (mainly ordinary) differential equations. The tools developed in differential algebra are useful for practical problem solving, but they must be used through computer algebra packages since computations can get very heavy. In this module, we will give special emphasis to the package "DifferentialAlgebra" included in the Maple kernel. We will give a rigorous but example led introduction to the main ideas of computer algebra. The main applications to be discussed are the analysis of singularities and the simplification of nonlinear differential systems. As already indicated, the module will have a strong computational flavour: Students will explore concrete examples with the computer algebra system Maple, comparing hand computations with the results achieved by the full-blown algorithms and dispatching large computations to the package. Outline Syllabus: Differential rings and field; differential ideals and homomorphisms; rankings; Ritt's reduction algorithm; characteristic sets; singular solutions.

MA995 Graphs and Combinatorics

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury	Autumn	M	15 (7.5)	80% Exam, 20% Coursework	

Contact Hours

42-48 lectures and example classes

Learning Outcomes

The intended subject specific learning outcomes
On successful completion of this module, students will:
1 have gained knowledge of the fundamental concepts and results in graph theory and combinatorics;
2 be able to describe and solve a mathematical problem using graphs and combinatorial arguments;
3 have gained further knowledge of discrete structures in mathematics;
4 have gained a working knowledge of various fundamental graph algorithms;
5 have an ability to understand constructive proofs and to be able to use them to design algorithms.
6 have a systematic understanding of an advanced topic in graph theory or combinatorics at the forefront of the discipline.

The intended generic learning outcomes
On successful completion of this module, students will have:
1 enhanced mathematical problem solving skills;
2 gained further appreciation of proofs in mathematics;
3 gained understanding of constructive proofs;
4 strengthened their skills in designing and working with algorithms;
5 an enhanced ability to communicate complex mathematical concepts.
6 an enhanced ability to master and communicate mathematics independently.

Method of Assessment

80% Examination, 20% Coursework

Preliminary Reading

P. Cameron, Combinatorics, Topics, Techniques Algorithms, Cambridge Press, (1994)
L. Lovasz, J. Pelikan, and K. Vesztergombi, Discrete Mathematics: Elementary and Beyond. Springer-Verlag, (2003).
D. B. West, Introduction to Graph Theory, Prentice Hall, (1996).
R.J. Wilson, Introduction to Graph Theory, Fourth edition. Longman, Harlow, (1996).

J.A. Bondy and U.S.R. Murty, Graph Theory, Graduate Text in Math. 244, Springer-Verlag, (2008).
B. Ballobas, Modern Graph Theory, Graduate Text in Math., 184, Springer-Verlag, 1998.

Synopsis *

Combinatorics is a field in mathematics that studies discrete, usually finite, structures, such as graphs. It not only plays an important role in numerous parts of mathematics, but also has real world applications. In particular, it underpins a variety of computational processes used in digital technologies and the design of computing hardware. Among other things, this module provides an introduction to graph theory. Graphs are discrete objects consisting of vertices that are connected by edges. We will discuss a variety of concepts and results in graph theory, and some fundamental graph algorithms. Topics may include, but are not restricted to, trees, shortest paths problems, walks on graphs, graph colourings and embeddings, flows and matchings, and matrices and graphs. In addition to graphs the module may cover other topics in combinatorics such as Ramsey theory, problems in extremal set theory, enumerative problems, Principle of Inclusion and Exclusion, and the P versus NP problem.

MAE100 School Practice

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
2	Canterbury Christ Church	Autumn	I	30 (15)	100% Coursework	

Synopsis *

This module encompasses the two placements completed during Year 2 - one in the role of Teaching Assistant and the other enabling you to teach some classes. It is assessed through a Record Of Development.

MAE101 MEKTT3RPSS: Reflective Professional Practice 2 Subject Studies Mathemat

Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury Christ Church	Autumn and Spring	H	40 (20)	100% Coursework	

Synopsis *

This module equips you to teach mathematics and considers all key aspects of mathematics pedagogy. It is assessed through an assignment and journal review that are equally weighted.

MAE102	MESTT3SE:Reflective Professional Practice 3 School Experience					
Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury Christ Church	Autumn and Spring	H	10 (5)	100% Coursework	

Synopsis *

This module is based on your first school placement and is assessed via coursework comprising of a Record of Development.

MAE103	MESTT3PI2:Professional Investigation 2 Teaching and Learning in Whole S					
Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury Christ Church	Autumn	H	20 (10)	100% Coursework	

Synopsis *

This module encompasses your final school placement.

MAE104	MEMTT3RPPS Reflective Professional Practice 1:Professional Studies					
Version	Campus	Term(s)	Level	Credit (ECTS)	Assessment	Convenor
1	Canterbury Christ Church	Autumn and Spring	H	20 (10)	100% Coursework	

Synopsis *

The focus of this module is teaching and learning and it considers generic issues such as how children learn and behaviour for learning. It is assessed via a portfolio of work and an assignment that are equally weighted.

We continually review and where appropriate, revise the range of modules on offer to reflect changes in the subject and ensure the best student experience. We will inform applicants of any changes to the course structure before enrolment.