

Mathematics and Statistics Undergraduate Handbook

Supplement to the Handbook

Honour School of Mathematics and Statistics Syllabus and Synopses for Part B 2013–2014 for examination in 2014

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Every effort is made to ensure that the list of courses offered is accurate at the time of going online. However, students are advised to check the up-to-date version of this document on the Department of Statistics website.

Notice of misprints or errors of any kind, and suggestions for improvements in this booklet should be addressed to the Academic Administrator in the Department of Statistics.

Updated 14 June 2013

1. Honour School of Mathematics and Statistics

See the current edition of the Examination Regulations at <http://www.admin.ox.ac.uk/examregs/> for the full regulations governing these examinations. The examination conventions can be found at http://www.stats.ox.ac.uk/current_students/bammath/examinations

In Part B each candidate shall offer a total of **eight units** from the schedule of units and double units.

- (a) Each candidate shall offer the double unit BS1.
- (b) Each candidate shall offer a total of at least two units from BS2 and BS3.
- (c) Each candidate may offer a total of at most two units from BS4 and the schedule of 'Other units'.
- (d) Each candidate may offer at most one double unit which is an Extended Essay or Structured Project.

Note: Units from the schedule of 'Mathematics Department units' for Part B of the Honour School of Mathematics are also available – see Section 3.

Note regarding (b) above: Since there is only the unit BS2a available under BS2, the following combinations (and only these) are permissible:

- (i) BS2a and BS3a;
- (ii) BS2a, BS3a and BS3b;
- (iii) BS3a and BS3b.

We ask that you register by the end of week 10 Trinity Term 2013 for classes for the Mathematics/ Statistics courses that you wish to take. A registration form is attached to these synopses. Some combinations of subjects are not advised and lectures in these subjects may clash. However, when timetabling lectures we will aim to keep clashes to a minimum.

Language Classes: If there are places available, Mathematics and Statistics students will be invited to apply to take classes in a foreign language. In 2013-2014 classes are offered in French and Spanish. Students' performance in these classes will not contribute to the degree classification in Mathematics and Statistics. However successful completion of the course may be recorded on student transcripts. See <http://www.maths.ox.ac.uk/current-students/undergraduates/handbooks-synopses/math> for further information.

2 **Statistics units and double units**

2.1 **BS1 Applied Statistics**

Level: H-level

Method of Assessment: written examination plus assessed practical assignments. The practical assignments contribute 1/3 of the marks for BS1. Please see below for the hand-in deadlines for practical assignments.

Weight: Double unit.

Prerequisites: Part A *Probability and Statistics*.

Aims

The course aims to develop the theory of statistical methods, and also to introduce students to the analysis of data using a statistical package. The main topics are: simulation based inference, practical aspects of linear models, logistic regression and generalized linear models, and robust and computer-intensive methods.

2.1.1 *BS1a Applied Statistics I* – 16 MT

Synopsis

Practical aspects of linear models and analysis of variance: multiple regression, model selection, fit criteria, use of residuals, outliers, leverage, model interpretation. Normal linear mixed models, hierarchical models.

Logistic regression. Linear exponential families and generalized linear models, scale parameter, link functions, canonical link. Maximum likelihood fitting and iterated weighted least squares. Asymptotic theory: statement and applications to inference, analysis of deviance, model checking, residuals.

2.1.2 *BS1b Applied Statistics II* – 10 HT

Synopsis

Inference using simulation methods. Nonparametric inference. Permutation tests. Rank statistics. Robust estimation. Breakdown point. Robust and resistant regression. Smoothing methods (local polynomials). Bootstrapping.

Reading (Michaelmas Term)

A. C. Davison, *Statistical Models*, CUP, 2003

J.J. Faraway, *Linear Models with R*, Chapman and Hall, 2005

A. J. Dobson and A.G Barnett, *An Introduction to Generalized Linear Models*, Chapman and Hall, 2008

J.J. Faraway, *Extending the Linear Model with R : Generalized Linear, Mixed Effects and Nonparametric Regression Models*, Chapman and Hall, 2006

Reading (Hilary Term)

P. J. Rousseeuw and A. M. Leroy, *Robust Regression and Outlier Detection*, Wiley (1987), pp 1-194.

J. D. Gibbons, *Nonparametric Statistical Inference*, Marcel Dekker (1985), pp 1-193, 273- 290.
R. H. Randles and D. A. Wolfe, *Introduction to the Theory of Nonparametric Statistics*, Wiley (1979), pp 1-322.

Further Reading

F. L. Ramsey and D. W. Schafer, *The Statistical Sleuth: A Course in Methods of Data Analysis*, 2nd edition, Duxbury (2002)
W. N. Venables and B. D. Ripley, *Modern Applied Statistics with S*, Springer (2002)
L. Wasserman, *All of Nonparametric Statistics*, Springer (2004)

Practicals

In addition to the lectures there will be five supervised practicals. Four of these contain problems whose written solutions will be assessed as part of the unit examination.

The hand-in deadlines for the four assessed practicals are:

1st practical: 12 noon Monday week 8, Michaelmas Term 2013
2nd practical: 12 noon Monday week 2, Hilary Term 2014
3rd practical: 12 noon Monday week 7, Hilary Term 2014
4th practical: 12 noon Monday week 2, Trinity Term 2014.

Candidates who miss the above deadlines may ask their college to apply to the Head of the Department of Statistics for permission to submit late. Where there is a valid reason, the Head of Department would normally approve the late submission without penalty. Where it is deemed that there is no valid reason, the Head of Department will advise the Examiners to apply a penalty in accordance with the late penalty tariff found in the Mathematics and Statistics Examination Conventions.

2.2 BS2a Foundations of Statistical Inference – 16 MT

Level: H-level

Method of Assessment: written examination

Weight: Unit

Prerequisites: Part A *Statistics* course. Part A *Probability* would be useful.

Learning outcomes

Understanding how data can be interpreted in the context of a statistical model. Working knowledge and understanding of key-elements of model-based statistical inference, including awareness of similarities, relationships and differences between Bayesian and frequentist approaches.

Synopsis

Exponential families: Curved and linear exponential families; canonical parametrization; likelihood equations. Sufficiency: Factorization theorem; sufficiency in exponential families.

Frequentist estimation: unbiasedness; method of moments; the Cramer-Rao information inequality; Rao-Blackwell theorem: Lehmann-Scheffé Theorem and Rao-Blackwellization; Statement of complete sufficiency for Exponential families.

The Bayesian paradigm: likelihood principal; subjective probability; prior to posterior analysis; asymptotic normality; conjugacy; examples from exponential families. Choice of prior distribution: proper and improper priors; Jeffreys' and maximum entropy priors. Hierarchical Bayes models.

Computational techniques: Markov chain Monte Carlo methods; The Metropolis-Hastings algorithm. Gibbs sampling. Variational Bayesian methods. The EM algorithm. Approximations to marginal likelihood: Laplace approximation and BIC.

Decision theory: risk function; Minimax rules, Bayes rules. Point estimators and admissibility of Bayes rules. The James-Stein estimator, shrinkage estimators and Empirical Bayes. Hypothesis testing as decision problem.

Reading

P. H. Garthwaite, I. T. Jolliffe and Byron Jones, *Statistical Inference*, Second ed. Oxford University Press, 2002

G.A.Young and R.L. Smith, *Essentials of Statistical Inference*, Cambridge University Press, 2005.

T. Leonard and J.S.J. Hsu, *Bayesian Methods*, Cambridge University Press, 2005.

Further reading

D. Barber, *Bayes Reasoning and Machine Learning*, Cambridge University Press, 2012

D. R. Cox, *Principles of Statistical Inference*, Cambridge University Press, 2006

H. Liero and S Zwanzig, *Introduction to the Theory of Statistical Inference*, CRC Press, 2012

2.3 **BS3**

A student obtaining at least an upper second class mark on the **units BS3a and BS3b together** can expect to gain exemption from the Institute of Actuaries' paper CT4, which is a compulsory paper in their cycle of professional actuarial examinations. An Independent Examiner approved by the Institute of Actuaries will inspect examination papers and scripts and **may adjust the pass requirements for exemptions**.

Please note that it is **not possible** to gain an exemption from the Institute of Actuaries paper CT4 if you do BS3a only. BS3a is a required prerequisite for BS3b.

2.3.1 BS3a Applied Probability – 16 MT

Level: H-level

Method of Assessment: written examination

Weight: Unit.

Prerequisite: Part A *Probability*.

Aims

This course is intended to show the power and range of probability by considering real examples in which probabilistic modelling is inescapable and useful. Theory will be developed as required to deal with the examples.

Synopsis

Poisson processes and birth processes. Continuous-time Markov chains. Transition rates, jump chains and holding times. Forward and backward equations. Class structure, hitting times and absorption probabilities. Recurrence and transience. Invariant distributions and limiting behaviour. Time reversal.

Renewal theory. Limit theorems: strong law of large numbers, strong law and central limit theorem of renewal theory, elementary renewal theorem, renewal theorem, key renewal theorem. Excess life, inspection paradox.

Applications in areas such as: queues and queueing networks - M/M/s queue, Erlang's formula, queues in tandem and networks of queues, M/G/1 and G/M/1 queues; insurance ruin models; applications in applied sciences.

Reading

- J.R. Norris: *Markov Chains*. Cambridge University Press (1997)
- G.R. Grimmett and D.R. Stirzaker: *Probability and Random Processes*. 3rd edition, Oxford University Press (2001)
- G.R. Grimmett and D.R. Stirzaker: *One Thousand Exercises in Probability*. Oxford University Press (2001)
- S.M. Ross: *Introduction to Probability Models*. 4th edition, Academic Press (1989)
- D.R. Stirzaker: *Elementary Probability*. 2nd edition, Cambridge University Press (2003)

2.3.2 BS3b Statistical Lifetime-Models – 16 HT

Level: H-level

Method of Assessment: written examination

Weight: Unit.

Prerequisites: Part A *Statistics*, BS3a *Applied Probability*

Aims

BS3b *Statistical Lifetime Models* follows on from BS3a *Applied Probability*. Models introduced there are examined more specifically in the context of measuring ‘lifetimes’ in the broad sense. In a life insurance context Markov transitions may model the passage from ‘alive’ to ‘dead’, possibly with intermediate stages like ‘loss of a limb’ or ‘critically ill’. The same models are used to model fertility transitions, the progress of a disease, and the reliability of a mechanical device. The aim is to develop statistical methods to estimate transition rates, and to use these transition rates to construct life tables that form the basis in the calculation of life insurance premiums and pension projections. We will also cover the basics of survival analysis, to model the influence of covariates (eg weight, smoking, use of a medication) on lifespans.

Synopsis

Life tables: Basic notation, life expectancy and remaining life expectancy, curtate lifetimes.

Census approximation, Lexis diagrams. Survival models: general lifetime distributions, force of mortality (hazard rate), survival function, the single decrement model and mortality in mixed populations.

Estimation procedures for lifetime distributions: empirical lifetime distributions, censoring and truncation, Kaplan-Meier estimate, Nelson-Aalen estimate. Parametric models, accelerated life models including Gompertz Weibull, log-normal, log-logistic. Plot-based methods for model selection. Cox regression. Proportional hazards, partial likelihood, semiparametric estimation of survival functions, use and overuse of proportional hazards in insurance calculations and epidemiology. Two-state and multiple-state Markov models, with simplifying assumptions. Estimation of Markovian transition rates: Maximum likelihood estimators, time-varying transition rates, census approximation. Life expectancy and occupation times in Markov models: eigenvector formalism. Applications to reliability, medical statistics, ecology.

Graduation, including fitting Gompertz-Makeham model, comparison with standard life table: tests including chi-square test and grouping of signs test, serial correlations test; smoothness. Application to pension plans.

Reading

- Subject 104 [CT4] *Survival models [Modelling] Core Reading*, Faculty & Institute of Actuaries
- D.R. Cox and D. Oakes: *Analysis of Survival Data*. Chapman & Hall (1984)

Further Reading

- J.P. Klein and M.L. Moeschberger: *Survival Analysis*. Springer (1997)
- C.T. Le: *Applied Survival Analysis*. 2nd edition Wiley (2003)

- H.U. Gerber: *Life Insurance Mathematics*. 3rd edition, Springer (1997)
- N.L. Bowers et al.: *Actuarial mathematics*. 2nd edition, Society of Actuaries (1997)

2.4 BS4 Actuarial Science

A student obtaining at least an upper second class mark on the **units BS4a and BS4b together** can expect to gain exemption from the Institute of Actuaries' paper CT1, which is a compulsory paper in their cycle of professional actuarial examinations. An Independent Examiner approved by the Institute of Actuaries will inspect examination papers and scripts and **may adjust the pass requirements for exemptions**.

Please note that it is **not possible** to gain an exemption from the Institute of Actuaries paper CT1 if you do BS4a only. BS4a is a required prerequisite for BS4b.

2.4.1 BS4a Actuarial Science I – 16 MT

Level: H-level

Method of Assessment: written examination

Weight: Unit.

Prerequisites: Part A *Probability* is useful, but not essential. If you have not done Part A *Probability*, make sure that you are familiar with Mods work on Probability.

Synopsis

Fundamental nature of actuarial work. Use of generalised cash flow model to describe financial transactions. Time value of money using the concepts of compound interest and discounting. Interest rate models. Present values and accumulated values of a stream of equal or unequal payments using specified rates of interest. Interest rates in terms of different time periods. Equation of value, rate of return of a cash flow, existence criteria.

Loan repayment schemes. Investment project appraisal, funds and weighted rates of return. Inflation modelling, inflation indices, real rates of return, inflation-adjustments. Valuation of fixed-interest securities, taxation and index-linked bonds.

Single decrement model. Present values and accumulated values of a stream of payments taking into account the probability of the payments being made according to a single decrement model. Annuity functions and assurance functions for a single decrement model. Risk and premium calculation.

Liabilities under a simple assurance contract or annuity contract. Premium reserves, Thiele's differential equation. Expenses and office premiums.

Reading

All of the following are available from the Publications Unit, Institute of Actuaries, 4 Worcester Street, Oxford OX1 2AW

- Subject 102 [CT1] *Financial Mathematics Core Reading* Faculty & Institute of Actuaries.

- J.J. McCutcheon and W.F. Scott: *An Introduction to the Mathematics of Finance*. Heinemann (1986)
- P. Zima and R.P. Brown: *Mathematics of Finance*. McGraw-Hill Ryerson (1993)
- N.L. Bowers et al: *Actuarial mathematics*. 2nd edition, Society of Actuaries (1997)
- J. Danthine and J. Donaldson: *Intermediate Financial Theory*. 2nd edition, Academic Press Advanced Finance (2005)

2.4.2 BS4b Actuarial Science II – 16 HT

Level: H-level

Method of Assessment: written examination

Weight: Unit.

Prerequisites: BS4a *Actuarial Science I*

Synopsis

Price and value of forward contracts. Term structure of interest rates, spot rates, forward rates and yield curves. Duration, convexity and immunisation. Simple stochastic interest rate models. Investment and risk characteristics of investments. Risk pooling.

Theories of value, St Petersburg Paradox, statement of Expected Utility Theory (EUT) and Subjective Expected Utility (SEU) representation theorems

Risk aversion, the Arrow-Pratt approximation, comparative risk aversion, classical utility functions.

First and second order stochastic dominance, the Rothschild-Stiglitz Proposition. EUT justification for insurance, Mossin's Theorem, Arrow's Theorem on the optimality of deductibles, static portfolio choice.

Desynchronisation and financial systems, Static exchange economy and Pareto efficiency, the mutuality principle, efficient allocation of aggregate risk.

Reading

All of the following are available from the Publications Unit, Institute of Actuaries, 4 Worcester Street, Oxford OX1 2AW

- Subject CT5[105] *Contingencies Core Reading* Faculty & Institute of Actuaries.
- H.U. Gerber: *Life Insurance Mathematics*. 3rd edition, Springer (1997)
- L. Eeckhoudt, C. Gollier and H.Schlesinger, *Economic and Financial Decisions under Risk*, Princeton University Press Princeton and Oxford, (2005), Chapters 1-4, 10
- C. Gollier: *The Economics of Risk and Time*, MIT Press (2001), Topics in chapters 1-4, 20
- Subject CT8: *Financial Economics Core reading*. Faculty & Institute of Actuaries, Units (i), (iii), (v)-(vi)
- N.L. Bowers et al: *Actuarial mathematics*. 2nd edition, Society of Actuaries (1997)

3 Mathematical and Other units

The other units that students in Part B Mathematics and Statistics may take are drawn from Part B of the Honour School of Mathematics.

For full details of these units, see the Syllabus and Synopses for Part B of the Honour School of Mathematics, which are available on the web at

<http://www.maths.ox.ac.uk/current-students/undergraduates/handbooks-synopses/math>

3.1 Mathematics units

The Mathematics units that are available are as follows:

B1a	Logic
B1b	Set Theory
B2a	Introduction to Representation Theory
B2b	Group Theory and an Introduction to Character Theory
B3a	Geometry of Surfaces
B3b	Algebraic Curves
B3.1a	Topology and Groups
B4a	Banach spaces
B4b	Hilbert Spaces (B4a is an essential pre-requisite)
B5a	Techniques of Applied Mathematics
B5b	Applied Partial Differential Equations
B5.1a	Dynamics and Energy Minimization
B6a	Viscous Flow
B6b	Waves and Compression Flow
B7.1a	Quantum mechanics
C7.1b	Quantum Theory and Quantum Computers (B7.1a is an essential pre-requisite)
B7.2b	Special Relativity and Electromagnetism (B7.1a is an essential pre-requisite)
B8a	Mathematical Ecology and Biology
B8b	Nonlinear Systems
B9a	Galois theory
B9b	Algebraic Number Theory (B9a is an essential pre-requisite)
B10a	Martingales through Measure Theory
B10b	Continuous Martingales and Stochastic Calculus
B10.1b	Mathematical Models of Financial Derivatives
B11a	Communication Theory
B11b	Graph Theory
B21a	Numerical Solution of Differential Equations I
B21b	Numerical Solution of Differential Equations II
B22a	Integer Programming

BE "Mathematical" Extended Essay [double unit]

or

BSP Structured Projects [double unit]

[Note: Students **cannot take both** BE and BSP]

(These are the units referred to in Section 1 as 'Mathematics Department units for Part B of the Honour School of Mathematics.)

See the “Projects Guidance Notes” on the web at <http://www.maths.ox.ac.uk/current-students/undergraduates/projects/> for more information on the Extended Essay option and an application form.

Please note that the following **are not permitted options** in Part B of the Honour School of Mathematics and Statistics:

- O1 History of Mathematics
- OE “Other Mathematical” Extended Essay

3.2 *Other units*

The other unit available is as follows:

- N1b Undergraduate Ambassadors Scheme

4. **Registration for Part B courses 2013-2014**

We ask that students register in advance for the classes they wish to take, by Friday of week 10 Trinity Term 2013, using the form overleaf.

Because of the large number of options which are available in Part B, some lectures will clash. See the Syllabus and Synopses for Part B of the Honour School of Mathematics for information on which lectures may clash <http://www.maths.ox.ac.uk/current-students/undergraduates/handbooks-synopses/math> .

REGISTRATION FORM: PART B CLASSES 2013-2014

SURNAME FIRST NAME

EMAIL ADDRESS

COLLEGE

Note: As described in Section 1, you need to do a total of 8 units in Part B: all Mathematics and Statistics students do the double unit BS1, and also at least two units from the units available under BS2 and BS3.

For the Statistics units BS1–BS4, and the Mathematics or Other units, please give details of subjects in which you wish to take classes.

I wish to take classes in the following subjects: [Please Tick]

✓	BS1 Applied Statistics (MT and HT, double unit, compulsory for Mathematics and Statistics students)
	BS2a Foundations of Statistical Inference (MT, unit)
✓	BS3a Applied Probability (MT, unit)
	BS3b Statistical Lifetime Models (HT, unit, BS3a is required pre-requisite)
	BS4a Actuarial Science I (MT unit)
	BS4b Actuarial Science II (HT, unit, BS4a is a required pre-requisite)

For Mathematics or Other units, please list the unit code and name:

Unit code Unit name

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Please return this form to the Academic Administrator, Department of Statistics, 1 South Parks Road, by Friday of week 10 Trinity Term 2013.