Mathematics and Statistics Undergraduate Handbook
Supplement to the Handbook

Honour School of Mathematics and Statistics
Syllabus and Synopses for Part B 2015–2016
for examination in 2016

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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 June 2015
1. **Honour School of Mathematics and Statistics**

1.1 Units and double-units and methods of examination

See the current edition of the Examination Regulations at [http://www.admin.ox.ac.uk/examregs/](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](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 SB1.
(b) Each candidate shall offer a total of at least two units from SB2 and SB3.
(c) Each candidate may offer a total of at most two units from SB4 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 SB2a available under SB2, the following combinations (and only these) are permissible:
(i) SB2a and SB3a;
(ii) SB2a, SB3a and SB3b;
(iii) SB3a and SB3b.

We ask that you register by the end of week 10 Trinity Term 2015 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.

1.2 **Language Classes**

If there are places available, Mathematics and Statistics students will be invited to apply to take classes in a foreign language. In 2015-2016 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 [https://www1.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/handbooks-synopses](https://www1.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/handbooks-synopses) for further information.

1.3 **Part B courses in future years**

In any year, most courses available in Part B that year will normally also be available in Part B the following year. However, sometimes new options will be added or existing options may
cease to run. The list of courses that will be available in Part B in any year will be published by the end of the preceding Trinity Term.

Details of Part C units, examinable in 2017, will be published before Michaelmas Term 2016.

1.4 Course list by term

The list of 2015-16 Part B courses by term is:

Michaelmas Term

SB1a  Applied Statistics I [double unit with SB1b]
SB2a  Foundations of Statistical Inference
SB3a  Applied Probability
SB4a  Actuarial Science I

Hilary Term

SB1b  Applied Statistics II [double unit with SB1a]
SB3b  Statistical Lifetime Models
SB4b  Actuarial Science II
2 Statistics units and double units

2.1 SB1 Applied Statistics

Level: H-level
Method of Assessment: written examination plus assessed practical assignments. The practical assignments contribute 1/3 of the marks for SB1. Please see below for the hand-in deadlines for practical assignments.
Weight: Double unit.

Prerequisites: A8 Probability and A9 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 SB1a Applied Statistics I – 16 MT

Synopsis


2.1.2 SB1b Applied Statistics II – 10 HT

Synopsis

Reading (Michaelmas Term)
A. C. Davison, Statistical Models, CUP, 2003
J.J. Faraway, Linear Models with R, Chapman and Hall , 2005
J.J. Faraway, Extending the Linear Model with R: Generalized Linear, Mixed Effects and Nonparametric Regression Models, Chapman and Hall, 2006

Reading (Hilary Term)
Further Reading


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 2015
2nd practical: 12 noon Monday week 2, Hilary Term 2016
3rd practical: 12 noon Monday week 7, Hilary Term 2016
4th practical: 12 noon Monday week 2, Trinity Term 2016.

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 **SB2a Foundations of Statistical Inference** – 16 MT

Level: H-level
Method of Assessment: written examination
Weight: Unit

Prerequisites: A9 Statistics. A8 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: 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

Further reading
D. Barber, Bayes Reasoning and Machine Learning, Cambridge University Press, 2012
D. R. Cox, Principles of Statistical Inference, Cambridge University Press, 2006

2.3 SB3

A student obtaining at least an upper second class mark on the units SB3a and SB3b 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 SB3a only. SB3a is a required prerequisite for SB3b.
2.3.1  **SB3a Applied Probability – 16 MT**

Level: H-level
Method of Assessment: written examination
Weight: Unit.

Prerequisite: **A8 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**


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**
2.3.2 SB3b Statistical Lifetime-Models – 16 HT

Level: H-level
Method of Assessment: written examination
Weight: Unit.

Prerequisites: A8 Statistics, SB3a Applied Probability

Aims
SB3b Statistical Lifetime Models follows on from SB3a 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


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

Further Reading
2.4 **SB4 Actuarial Science**

A student obtaining at least an upper second class mark on the units **SB4a and SB4b 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 SB4a only. SB4a is a required prerequisite for SB4b.

2.4.1 **SB4a Actuarial Science I – 16 MT**

**Level:** H-level  
**Method of Assessment:** written examination  
**Weight:** Unit.

**Prerequisites:** A8 *Probability* is useful, but not essential. If you have not done A8 *Probability*, make sure that you are familiar with Prelims 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.  
2.4.2 SB4b Actuarial Science II – 16 HT

Level: H-level  
Method of Assessment: written examination  
Weight: Unit.

Prerequisites: SB4a Actuarial Science I

Synopsis

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.  
• 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)  
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 [https://www1.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/handbooks-synopses](https://www1.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/handbooks-synopses)

### 3.1 Mathematics units

The Mathematics units that are available are as follows:

- **B1.1:** Logic 16 MT
- **B1.2:** Set Theory 16 HT
- **B2.1:** Introduction to Representation Theory 16 MT
- **B2.2:** Commutative Algebra 16 MT
- **B3.1:** Galois Theory 16 MT
- **B3.2:** Geometry of Surfaces 16 MT
- **B3.3:** Algebraic Curves 16 HT
- **B3.4:** Algebraic Number Theory 16 HT
- **B3.5:** Topology and Groups 16 MT
- **B4.1:** Banach Spaces 16 MT
- **B4.2:** Hilbert Spaces 16 HT
- **B4.3:** Dynamical Systems and Energy Minimization 16 MT
- **B5.1:** Stochastic Modelling of Biological Processes 16 MT
- **B5.2:** Applied Partial Differential Equations 16 HT
- **B5.3:** Viscous Flow 16 MT
- **B5.4:** Waves and Compressible Flow 16 HT
- **B5.5:** Mathematical Ecology and Biology 16 MT
- **B5.6:** Nonlinear Systems 16 HT
- **B6.1** Numerical Solution of Differential Equations I 16 MT
- **B6.2** Numerical Solution of Differential Equations II 16 HT
- **B6.3** Integer Programming 16 MT
- **B7.1** Classical Mechanics 16 HT
- **B7.2** Electromagnetism 16 MT
- **C7.3** Further Quantum Theory 16 HT
- **B8.1:** Martingales Through Measure Theory 16 MT
- **B8.2:** Continuous Martingales and Stochastic Calculus 16 HT
- **B8.3:** Mathematical Models of Financial Derivatives 16 HT
- **B8.4:** Communication Theory 16 MT
- **B8.5:** Graph Theory 16 HT

**BEE Mathematical Extended Essay**  MT & HT [double unit]

or

**BSP: Structured Projects**  MT & HT [double unit]

[Note: Students cannot take both BEE and BSP]

Other units:

- **BN1:** Undergraduate Ambassadors’ Scheme  MT & HT [double unit]

or
BN1.1: Mathematics Education

(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 https://www1.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/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:

BO1.1 History of Mathematics
BOE “Other Mathematical” Extended Essay

3.2 Other units

The other units available are as follows:
BN1: Undergraduate Ambassadors’ Scheme MT & HT [double unit]
or
BN1.1: Mathematics Education MT

4. Registration for Part B courses 2015-2016

We ask that students register in advance for the classes they wish to take, by Friday of week 10 Trinity Term 2015, using the form overleaf.

Because of the large number of options which are available in Part B, some lectures will clash.
REGISTRATION FORM: PART B CLASSES 2015-2016

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 SB1, and also at least two units from the units available under SB2 and SB3.

For the Statistics units SB1–SB4, 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]

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<thead>
<tr>
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<tbody>
<tr>
<td>✓ SB1</td>
<td>Applied Statistics (MT and HT, double unit, compulsory for Mathematics and Statistics students)</td>
</tr>
<tr>
<td></td>
<td>SB2a Foundations of Statistical Inference (MT, unit)</td>
</tr>
<tr>
<td>✓ SB3a</td>
<td>Applied Probability (MT, unit)</td>
</tr>
<tr>
<td></td>
<td>SB3b Statistical Lifetime Models (HT, unit, SB3a is required pre-requisite)</td>
</tr>
<tr>
<td></td>
<td>SB4a Actuarial Science I (MT unit)</td>
</tr>
<tr>
<td></td>
<td>SB4b Actuarial Science II (HT, unit, SB4a is a required pre-requisite)</td>
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</tbody>
</table>

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 2015.