Honour School of Mathematics and Statistics
Syllabus and Synopses for Part B 2019–2020
for examination in 2020

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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 (academic.administrator@stats.ox.ac.uk).

Updated September 2019
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/2017-18/hsomathandstat/studentview/](http://www.admin.ox.ac.uk/examregs/2017-18/hsomathandstat/studentview/) 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.

Students are asked to register for the options they intend to take by the end of week 10, Trinity Term 2019 using the Mathematical Institute course management portal. [https://courses.maths.ox.ac.uk/](https://courses.maths.ox.ac.uk/). Students may alter the options they have registered for after this but it is helpful if their registration is as accurate as possible. Students will then be asked to sign up for classes at the start of Michaelmas Term 2019. Students who register for a course or courses for which there is a quota should consider registering for an additional course (by way of a "reserve choice") in case they do not receive a place on the course with the quota.

Every effort will be made when timetabling lectures to ensure that mathematics lectures do not clash. However, because of the large number of options this may sometimes be unavoidable.

1.2 **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 2021, will be published before Michaelmas Term 2020.
1.3 Course list by term

The list of 2019-2020 Part B courses by term is:

Michaelmas Term

SB1.1 Applied Statistics [double unit with SB1.2]
SB2.1 Foundations of Statistical Inference
SB4.1 Actuarial Science

Hilary Term

SB1.2 Computational Statistics [double unit with SB1.1]
SB2.2 Statistical Machine Learning
SB3.1 Applied Probability
SB3.2 Statistical Lifetime Models
2 Statistics units and double units

2.1 SB1 Applied and Computational 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 computer-intensive methods.

2.1.1 SB1.1 Applied Statistics – 13 MT

Synopsis
The normal linear model: use of matrices, least squares and maximum likelihood estimation, normal equations, distribution theory for the normal model, hypothesis tests and confidence intervals.

Practical aspects of linear models and analysis of variance: multiple regression, categorical variables and interactions, blocks and treatments, orthogonality, model selection (including AIC, but not the derivation of AIC), fit criteria, use of residuals, outliers, leverage, model interpretation.

Normal linear mixed models, hierarchical models.


Reading
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
Further Reading

2.1.2 SB1.2 Computational Statistics – 13 HT

Synopsis
Smoothing methods (local polynomials). Nonparametric inference (bandwidth and Generalised Cross Validation).
Multivariate smoothers and Generalised Additive Models.


Bootstrapping.


Reading

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 2019
2nd practical: 12 noon Monday week 2, Hilary Term 2020
3rd practical: 12 noon Monday week 8, Hilary Term 2020
4th practical: 12 noon Monday week 2, Trinity Term 2020.

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.

2.2.1 SB2.1 Foundations of Statistical Inference – 16 MT

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

Prerequisites: A9 Statistics, A8 Probability.

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.

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
2.2.2 **SB2.2 Statistical Machine Learning – 16 HT**

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

**Recommended prerequisites:** Part A A9 Statistics and A8 Probability. SB2a Foundations of Statistical Inference useful but not essential.

**Aims and Objectives**

Machine learning studies methods that can automatically detect patterns in data, and then use these patterns to predict future data or other outcomes of interest. It is widely used across many scientific and engineering disciplines.

This course covers statistical fundamentals of machine learning, with a focus on supervised learning and empirical risk minimisation. Both generative and discriminative learning frameworks are discussed and a variety of widely used classification algorithms are overviewed.

**Synopsis**


Neural networks and deep learning.

**Reading**


**Further Reading**


2.3.1 **SB3.1 Applied Probability – 16 HT**

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

**Prerequisite:** A8 Probability.
**Aims and Objectives**
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 SB3.2 Statistical Lifetime-Models – 16 HT**

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

**Prerequisite:** A9 Statistics.

**Aims and Objectives**
Event times and event counts appear in many social and medical data contexts, and require a specialised suite of techniques to handle properly, broadly known as survival analysis. This course covers the basic definitions of hazard rates and survival functions, techniques for creating and interpreting life tables, nonparametric estimation and comparison of event-time distributions, and evaluating the goodness of fit of various semiparametric models. A focus is on understanding when and why particular models ought to be chosen, and on using the standard software tools in R to carry out data analysis.
Synopsis
1. Introduction to survival data: hazard rates, survival curves, life tables.
2. Censoring and truncation, introduction through the census approximation.
3. Parametric survival models.
5. Nonparametric model tests (log-rank test and relatives).
6. Semiparametric models
   a. Proportional hazards;
   b. Additive hazards;
   c. Accelerated failure models.
7. Model-fit diagnostics.
8. Dynamic prediction and model information quality.
9. Repeated events.

Topics:

Life tables: Basic notation, life expectancy and remaining life expectancy, curtate lifetimes.
Survival models: general lifetime distributions, force of mortality (hazard rate), survival function.

Applications in epidemiology. Parametric models generalised linear regression. Nonparametric comparison of survival distributions, including log-rank test and serial-correlations test. Using the survival package in R.

Relative risk (proportional hazards) including the Cox model, additive hazards model, accelerated failure models. Partial likelihood. Efron’s estimator for survival distributions.

Residual tests, including Cox—Snell residuals, martingale residuals, Schoenfeld residuals.
Dynamic prediction and predictive power of models: Cross validation,

Anderson—Gill model, Poisson regression, negative binomial model. Multistate models and Markov processes.

Reading
Statistical Lifetime Models lecture notes, revised 2019.


Further Reading
Subject CT4 Models Core Reading, Faculty & Institute of Actuaries.

2.4 **SB4.1 Actuarial Science**– 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.
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.
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.
Mossin’s Theorem, static portfolio choice. Consumption and saving. Felicity Function and Prudence.
Time consistency. Desynchronisation.

**Reading**
Subject CT1 Financial Mathematics Core Reading Institute & Faculty of Actuaries.
Subject CT5, Contingencies Core Reading, Institute & Faculty of Actuaries.
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 https://courses.maths.ox.ac.uk/overview/undergraduate.

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 HT
- 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: Functional Analysis I 16 MT
- B4.2: Functional Analysis II 16 HT
- B4.3 Distribution theory and Analysis of PDE 16 MT
- B5.1: Stochastic Modelling of Biological Processes 16 HT
- B5.2: Applied Partial Differential Equations 16 MT
- B5.3: Viscous Flow 16 MT
- B5.4: Waves and Compressible Flow 16 HT
- B5.5: Further Mathematical 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 MT
- B7.2 Electromagnetism 16 MT
- B7.3 Further Quantum Theory 16 HT
- B8.1: Probability, Measure and Martingales 16 MT
- B8.2: Continuous Martingales and Stochastic Calculus 16 HT
- B8.3: Mathematical Models of Financial Derivatives 16 HT
- B8.4: Information Theory 16 MT
- B8.5: Graph Theory 16 MT
- OCS2: Computational Complexity 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: Mathematical Education and Undergraduate
- BN1.2: Ambassadors' Scheme  HT

or

- BN1.1: Mathematics Education  MT
(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://www.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/projects for more information on the Extended Essay option.

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: Mathematical Education and Undergraduate
BN1.2: Ambassadors' Scheme HT
or
BN1.1: Mathematics Education MT