Mathematics and Statistics Undergraduate Handbook
Supplement to the Handbook

Honour School of Mathematics and Statistics
Syllabus and Synopses for Part B 2021–2022
for examination in 2022

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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 August 2021
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 [https://examregs.admin.ox.ac.uk](https://examregs.admin.ox.ac.uk) for the full regulations governing these examinations. The examination conventions can be found at Canvas Mathematics and Statistics Part B Examinations and Assessments.

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 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 2021 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 2021. 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 2023, will be published before Michaelmas Term 2022.
1.3 Course list by term

The list of 2021-2022 Part B courses by term is:

Michaelmas Term

SB1.1 Applied Statistics [double unit with SB1.2]
SB2.1 Foundations of Statistical Inference
SB3.2 Statistical Lifetime Models

Hilary Term

SB1.2 Computational Statistics [double unit with SB1.1]
SB2.2 Statistical Machine Learning
SB3.1 Applied Probability
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 2021
2nd practical: 12 noon Monday week 2, Hilary Term 2022
3rd practical: 12 noon Monday week 8, Hilary Term 2022
4th practical: 12 noon Monday week 2, Trinity Term 2022.

It is expected that submissions will be made online via the Inspera system. Details of how to submit will be provided during Michaelmas Term.

Candidates who miss the above deadlines may ask their college to apply to the Proctors’ Office for permission to submit late.
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**
Performance measures, ROC curves. K-nearest neighbours as an example classifier.
Decision trees, bagging, random forests, boosting.
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; stochastic epidemic models.

Reading
2.3.2  SB3.2 Statistical Lifetime-Models – 16 MT

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 diagnostics.
8. Repeated events.

Topics:


Relative risk (proportional hazards) including the Cox model, additive hazards model, accelerated failure models. Partial likelihood. Efron and Breslow estimators for survival distributions.

Model diagnostics, including residual methods and predictive power.

Correlated and repeated events, including Anderson—Gill model, Poisson regression, negative binomial model.
**Reading**
Statistical Lifetime Models lecture notes, revised 2019.


**Further Reading**
Subject CT4 Models Core Reading, Faculty & Institute 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/course/index.php?categoryid=6](https://courses.maths.ox.ac.uk/course/index.php?categoryid=6)

### 3.1 Mathematics units

The Mathematics units that are available are as follows:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1.1: Logic</td>
<td>16 MT</td>
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<tr>
<td>B1.2: Set Theory</td>
<td>16 HT</td>
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<tr>
<td>B2.1: Introduction to Representation Theory</td>
<td>16 MT</td>
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<tr>
<td>B2.2: Commutative Algebra</td>
<td>16 HT</td>
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<tr>
<td>B3.1: Galois Theory</td>
<td>16 MT</td>
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<tr>
<td>B3.2: Geometry of Surfaces</td>
<td>16 MT</td>
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<tr>
<td>B3.3: Algebraic Curves</td>
<td>16 HT</td>
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<tr>
<td>B3.4: Algebraic Number Theory</td>
<td>16 HT</td>
</tr>
<tr>
<td>B3.5: Topology and Groups</td>
<td>16 MT</td>
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<tr>
<td>B4.1: Functional Analysis I</td>
<td>16 MT</td>
</tr>
<tr>
<td>B4.2: Functional Analysis II</td>
<td>16 HT</td>
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<tr>
<td>B4.3: Distribution Theory</td>
<td>16 MT</td>
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<tr>
<td>B4.4: Fourier Analysis</td>
<td>16 HT</td>
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<tr>
<td>B5.1: Stochastic Modelling of Biological Processes</td>
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<tr>
<td>B5.2: Applied Partial Differential Equations</td>
<td>16 MT</td>
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<tr>
<td>B5.3: Viscous Flow</td>
<td>16 MT</td>
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<tr>
<td>B5.4: Waves and Compressible Flow</td>
<td>16 HT</td>
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<tr>
<td>B5.5: Further Mathematical Biology</td>
<td>16 MT</td>
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<td>B5.6: Nonlinear Systems</td>
<td>16 HT</td>
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<tr>
<td>B6.1: Numerical Solution of Partial Differential Equations</td>
<td>16 MT</td>
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<td>B6.2: Optimisation for Data Science</td>
<td>16 HT</td>
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<td>B6.3: Integer Programming</td>
<td>16 MT</td>
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<tr>
<td>B7.1: Classical Mechanics</td>
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<tr>
<td>B7.2: Electromagnetism</td>
<td>16 HT</td>
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<td>B7.3: Further Quantum Theory</td>
<td>16 HT</td>
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<tr>
<td>B8.1: Probability, Measure and Martingales</td>
<td>16 MT</td>
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<tr>
<td>B8.2: Continuous Martingales and Stochastic Calculus</td>
<td>16 HT</td>
</tr>
<tr>
<td>B8.3: Mathematical Models of Financial Derivatives</td>
<td>16 HT</td>
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<tr>
<td>B8.4: Information Theory</td>
<td>16 HT</td>
</tr>
<tr>
<td>B8.5: Graph Theory</td>
<td>16 MT</td>
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<tr>
<td>OCS2: Computational Complexity</td>
<td>16 HT</td>
</tr>
</tbody>
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**BEE Mathematical Extended Essay**

MT & HT [double unit]

or

**BSP: Structured Projects**

MT & HT [double unit]

[Note: Students cannot take both BEE and BSP]

The units above 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](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 units in this subsection, Section 3.2, are those referred to in (c) of Section 1 as the schedule of 'Other units'.

The other units available are as follows:

None this year.

(BN1.1 Mathematics Education and BN 1.2 Undergraduate Ambassadors' Scheme are not running this year.)