# Mathematics and Statistics Undergraduate Handbook

## Supplement to the Handbook

### Honour School of Mathematics and Statistics

Syllabus and Synopses for Part B 2023–2024

for examination in 2024

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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).

Version 1.1 – History of Maths added to other units section.

October 2023
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 on the Canvas course examinations and assessment page.

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 2023 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 2023. 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 2025, will be published before Michaelmas Term 2024.
1.3 Course list by term

The list of 2023-2024 Part B courses by term is:

Michaelmas Term

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

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 2023
2nd practical: 12 noon Monday week 2, Hilary Term 2024
3rd practical: 12 noon Monday week 8, Hilary Term 2024
4th practical: 12 noon Monday week 2, Trinity Term 2024.

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. SB2.1 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 and regression algorithms are overviewed.

**Synopsis**
Generative classifiers: Linear and quadratic discriminant analysis, naive Bayes.
Further concepts in statistical machine learning: feature expansion, overfitting and bias-variance trade-off, double descent phenomenon and overparameterisation; cross-validation, performance measures, ROC curves
Optimisation for Machine learning: gradient descent and stochastic gradient descent, early stopping
Linear classifiers: least-squares, perceptron, logistic regression
K-nearest neighbours
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**
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=735

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
B2.3: Lie Algebras 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: Functional Analysis I 16 MT
B4.2: Functional Analysis II 16 HT
B4.3 Distribution Theory 16 MT
B4.4 Fourier Analysis 16 HT
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 Dynamics, Bifurcations and Chaos 16 HT
B6.1 Numerical Solution of Partial Differential Equations 16 MT
B6.2 Optimisation for Data Science 16 HT
B6.3 Integer Programming 16 MT
B7.1 Classical Mechanics 16 MT
B7.2 Electromagnetism 16 HT
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 HT
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]

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 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:

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:

- **BO1.1 History of Mathematics**

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