School Of Mathematics and Statistics
Single Honours Mathematics

BSc Mathematics
MMath Mathematics
BSc Mathematics and Statistics
MMath Mathematics and Statistics
BSc Financial Mathematics
BSc Mathematics with Spanish Language
MMath Mathematics with Spanish Language
BSc Mathematics with French Language
MMath Mathematics with French Language
BSc Mathematics with German Language
MMath Mathematics with German Language
BSc Mathematics with Study in Europe
MMath Mathematics with Study in Europe
MMath Mathematics with a Year Abroad

4 year MMath and 3 year BSc
Level Three and Level Four
Mathematics and Statistics Courses
2021/2022 and 2022/2023
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1 Introduction

This handbook provides information of a general nature, and also information about course structures and individual modules, for students who expect to enter, in September 2021, the third or fourth years of one of the following degree programmes:

- the three-year BSc Mathematics programme;
- the four-year MMath Mathematics programme;
- the three-year BSc Mathematics and Statistics programme;
- the four-year MMath Mathematics and Statistics programme;
- the three-year BSc Financial Mathematics programme;
- the four-year MMath Mathematics with Study in Europe programme;
- the four-year BSc Mathematics with Study in Europe programme;
- the four-year MMath Mathematics with French, German or Spanish Language programme;
- the four-year BSc Mathematics with French, German or Spanish Language programme;
- the four-year MMath Mathematics with a Year Abroad programme.

This booklet is particularly aimed at those students who are in their second year in 2020–2021 of the Single Honours BSc or MMath Mathematics programmes.

The MMath degree is designed above all for those who enjoy mathematics and appreciate a challenge. It will be particularly appropriate for those who are considering careers as professional mathematicians or statisticians (for example, as researchers in industry or higher education). The BSc degree emphasizes problem solving, conceptual and abstract thinking, and communication skills. University Regulations state that students can normally continue into Level 3 of an MMath programme only if they have obtained 120 credits at Level 2 with a weighted mean grade of at least 59.5.

This booklet contains essential information to help you to make informed choices; it will be useful throughout your third (and fourth) year. You are welcome to seek further information or advice from your personal tutor, the Senior Tutor or Programme Leader for your degree programme.

Dr. Simon Willerton, Director of Teaching, SoMaS
2 Disclaimer

Every care has been taken to ensure the accuracy of the information in this booklet. To the best of our knowledge it was correct at the time at which it was prepared. The School of Mathematics and Statistics cannot accept responsibility for any errors which could occur should there be any further modification of the Regulations.

There have been a number of staff changes in the School in recent years with several new lecturers arriving and some older staff leaving. Further changes of this kind may well occur. Courses at Levels 3 and 4 are specialized and the School cannot guarantee to run a course for which the qualified lecturer leaves. On the other hand additional options may be offered when staff with new interests arrive. Also, there could be changes in the syllabus and timing, particularly of courses in 2022–2023.

In addition the School reserves the right to withdraw courses for which the number of students registered is very low.
3 Administrative Information

Dates of Semesters

Session 2021–2022

2021
27 September – 18 December Autumn Semester Teaching Period (12 weeks)

2022
17 January – 5 February Autumn Semester Examinations (3 weeks)
7 February – 2 April Spring Semester, First Teaching Period (8 weeks)
25 April – 20 May Spring Semester, Second Teaching Period (4 weeks)
23 May – 11 June Spring Semester Examinations (3 weeks).

Session 2022–2023

2022
26 September – 17 December Autumn Semester Teaching Period (12 weeks)

2023
16 January – 4 February Autumn Semester Examinations (3 weeks)
6 February – 1 April Spring Semester, First Teaching Period (8 weeks)
24 April – 19 May Spring Semester, Second Teaching Period (4 weeks)
22 May – 10 June Spring Semester Examinations (3 weeks).

Organisation of Modules

Most Level 3 and 4 Mathematics and Statistics modules are delivered at the rate of 2 hours of lectures per week; project modules are among the exceptions to this. Your lecturers will make appropriate arrangements for times when you can consult them.

Choice of Degree Programme

Those of you registered for an MMath degree now have to decide whether to remain on the degree, or to transfer to the three-year BSc Mathematics degree. It will be necessary for you to obtain 120 credits at Level 2 with an average of at least 59.5 in order for you to progress to Level 3 of the MMath degree, and therefore if you do not achieve this then your transfer will be automatic. If you decide to transfer to the BSc degree, then Student Finance England (or other funding body if applicable) will be notified by the University. For this reason, you should not elect to transfer to the BSc degree unless you are absolutely sure of that decision. It will be possible to make the change when you return after the summer vacation, although we anticipate that most students will have made a decision one way or the other by the beginning of the summer vacation. It is also (normally) possible for you to transfer from an MMath programme to a BSc programme during your third year, but please note that you would only be able to take part in the Degree Ceremony in July 2022 if you transferred by March 2022.
Those of you registered for a three-year BSc degree programme may also decide that you wish to transfer to a four-year MMath programme (assuming that you obtain 120 credits at Level 2 with an average of at least 59.5). The right to switch is not automatic, even with 120 credits at Level 2 and an average of 59.5, and you should discuss your situation with the Senior Tutor. You are also advised to consult Student Finance England or other funding body to check that they have no objection.

Choice of Modules

Once you have decided on your degree programme, you will need to decide which modules you wish to take in the coming year, or two years if you are to take the MMath. This choice can certainly be regarded as provisional at this stage; however, you should try to decide on a probable selection this semester while you are in a position to consult staff in the School.

Each year you must choose modules to the value of 120 credits in accordance with the Regulations for your degree.

Online module choice in 2021 runs from 4 May – 21 May. You should ensure that you submit your choice of modules during this period. Details of the operation of online module choice can be found at https://www.sheffield.ac.uk/registration/continuing/module.

There are good reasons why it is strongly advisable that MMath students should plan their choices for both of their final two years. There is a requirement that graduates from Masters programmes should take at least 120 credits of Level 4 modules (i.e., those modules with 4** or 6**** codes). There is a requirement that at least 40 credits of Level 4 modules are in the form of project modules, but this still leaves MMath students (including those whose third year is spent abroad) needing to take a further 80 credits of other Level 4 modules. Such Level 4 modules often have Level 3 prerequisites, so you need to be sure that you acquire the prerequisites in 2021–2022 (even if you are studying abroad) for the Level 4 courses you are to take in 2022–2023. Secondly, some Level 4 courses are enhanced versions of Level 3 courses and so cannot be taken after the Level 3 courses on which they are based. Again, you need to ensure that your choice of options leaves you with a desirable choice for the fourth year.

MMath Mathematics with Spanish/French/German Language students are required to take, in their fourth year, the 40 credits of compulsory project modules, but only 40 further credits of Level 4 SoMaS modules; their remaining 40 credits in their fourth year comprise study in the foreign language.

Additional Optional Modules

Some of our programmes used to offer unrestricted module choice. This has now been discontinued. If your course used to include unrestricted modules, a list of optional modules have been provided for you to choose from. You can also choose from Languages for All modules (https://www.sheffield.ac.uk/languages/lfa/modules). The marks from such modules are used in assessing your final degree classifications. It is your responsibility to determine the prerequisites and timetable for any non-mathematical module and to obtain academic approval from the department which owns the module. The timetable for 2020–2021 is the best available guide, but this is subject to change for 2021–2022, and choices may need to be changed when the final timetable for 2021–2022 is known in September.
Note that some mathematics and statistics modules cannot be taken with certain modules from other departments; details are included in the information on individual modules.

**Change of Choice of Modules**

The University allows you to change your choice of modules during three weeks at the beginning of the semester. *If you do change your options early in a semester it is your responsibility to ensure not only that your timetable for that semester works but also that you will have suitable options available in future semesters for you to be able to complete your degree* (for example, you will have covered all prerequisites for your future choices). Change of choice of modules is done online.

The system can be accessed via MUSE. Log in as normal and go to the My Services tab then View all services for the link to the online system (under M - Module Add/Drop). Follow the simple instructions on screen. Your core modules will already be listed when you access the online add/drop screens. Once you have entered and submitted your request to add and drop optional modules, your department will check and approve, or decline, your choices. You will receive an automated email, confirming when your record has been updated. If there are any problems with your choices, you will receive an email from your department advising you what action to take.

The online system is not available to distance learning students or to students taking modules in the Institute of Lifelong Learning. They will need to use the paper ‘Add-Drop’ form. Add-Drop forms are available from the Student Services Information Desk (SSiD) in the Union of Students, and can also be downloaded from the SSiD web site at https://www.sheffield.ac.uk/ssid/forms. When you have completed the form, you must have it signed, to signify the School’s approval, by the Programme Leader for your degree programme – see the “Making changes” section of https://sheffield.ac.uk/maths/current/admin. The form should then be handed in at Hicks F10.

You can access the record of your choice of modules on central records. You must check that this record is correct in the fourth week of each semester. If it is not you will need to make the appropriate changes online or using an Add-Drop form.

**Progression into the Third Year**

Since your Level 2 results contribute to your overall degree classification (unlike your Level 1 results), the rules for progression from Level 2 into Level 3 are slightly more involved.

For students on **BSc** degree programmes, the rules for progression from Level 2 to Level 3 are given below, and apply to the January and June exams taken together:

(i) You may progress to Level 3 without any resit if you have obtained 120 credits in your Level 2 modules.

(ii) The Examiners have discretion to decide whether students who have been awarded 100 or 110 such credits may be deemed to have passed at Level 2 and permitted to proceed to Level 3. Permission to proceed in these circumstances is **NOT** automatic.

If you have obtained at least 100 credits but have failed one or two modules at Level 2, then you are strongly advised to resit any failed modules (even if the Examiners permit
you to progress), because in all cases there is a minimum number of credits that must be
obtained (over the second and subsequent years combined) if the degree is to be awarded.

(iii) If you have only 90 or fewer credits then you must resit ALL the modules you have failed.

Note that for any Level 2 module you are only allowed ONE resit attempt (not including cases
for which you are ‘Not Assessed’). If you are unable to pass Level 2 after the maximum number
of attempts at each module, you will not be able to continue with your degree.

If you wish to retake failed modules you should follow the instructions at https://www.
sheffield.ac.uk/ssid/assessment/resits-reassessment/ug. Any international stu-
dent who wishes to take August 2022 resit examinations in their home country should apply
to do so by the end of the Semester 2 examination period 2022. Further details can be found at
https://www.sheffield.ac.uk/ssid/assessment/resits-reassessment/overseas

The maximum score that can be credited as a result of a resit examination is 40.

Students on an MMath programme must, at the first attempt, obtain 120 credits at Level
2 with an average of at least 59.5 to be permitted to progress to Level 3 of the same pro-
gramme; those who do not meet this requirement will be transferred to a BSc programme.
For students on the MMath Mathematics with Study in Europe or one of the MMath with
Spanish/French/German Language degrees this average is calculated only for the MAS mod-
ules.

Students on the MMath/BSc Mathematics with Study in Europe or one of the MMath/BSc
with Spanish/French/German Language degrees must normally obtain an average of at least
55 in the MLT units at Level 2 to be permitted to progress to Level 3 of those programmes.
Those who do not meet this requirement will be transferred to MMath Mathematics or BSc
Mathematics.

Progression into the Fourth Year

The Examiners may in their discretion recommend that a student on an MMath programme
who is awarded not fewer than 100 credits at Level 3 and who obtains a weighted mean grade
of not lower than 59.5 at Level 3 be permitted to proceed to Level 4.

This is not automatic, and students towards the bottom end of this region, or students with
any fail marks, should not expect to be permitted to progress; experience has shown that such
students struggle with the additional difficulty of Level 4. If students are not permitted to
progress, then students may be eligible for a BSc degree.

A student who is permitted to progress from Level 3 to Level 4, with fewer than 120 credits
from the Level 3 year, may resit failed Level 3 modules once during the Level 4 year. The resit
mark will be capped at 40 for modules with a 3** or a 3**** code, and at 50 for modules
with a 4** or a 6**** code. If the resit mark is lower than the original, the higher mark will
be used in the final assessment.

Incorporating Employment into your Degree

The University of Sheffield recognises that both students and employers value the benefits that
structured work experience can provide as part of a university degree programme. We have
two options for incorporating a year in employment into your degree:

(i) If you began your degree in Autumn 2018 or later, you may be able to transfer to one of our four “with Placement Year” programmes. In principle, this can be done at any point prior to your final year, subject to agreement by SoMaS. If you are in your penultimate year, you may need to find a placement before being allowed to transfer. These programmes incorporate extra support for finding a placement and developing employability skills, beyond those available to other undergraduates.

(ii) If you find a placement during your penultimate year, you can add “with Employment Experience” to any of our (non-Placement Year) programmes, subject to successful completion of the placement. This requires transferring degree programmes, which needs to be approved by SoMaS (and any other appropriate departments, for dual degrees).

Under either scheme, you will spend your penultimate year (i.e. the year between Levels 2 and 3 of a three year degree, or between Levels 3 and 4 of a four year degree) in employment. Students typically return from their placement year confident and highly-motivated, often with a graduate job lined up for after their degree.

The placement should involve work connected with your degree programme or with your proposed future employment. We recognize that many mathematics graduates go into graduate jobs that do not use their degree directly. Therefore a placement with, for example, an accountancy firm would be acceptable even if it did not involve the use of university-level mathematics. Students need to find their own company placement and the SoMaS Employability Lead needs to validate the placement. Mathematics students are very much in demand for year-long placements, and many companies with interesting jobs for mathematicians are willing to invest the training effort in year-long placements.

You will typically need to start planning for the placement a year before it starts. You are responsible for getting the placement, but the Careers Service can assist. Those on the Placement Year programme will also have help on offer from the Placement Year Programme Lead.

Your placement will be assessed on a pass or fail basis. It will not count towards your final degree classification; however, you will need to pass a formal assessment and complete the placement year in order to gain the amended degree title. You will be required to complete and submit:

- A skills analysis (1600-2000 words), identifying specific skills that you have gained and/or developed over the course of your placement,
- A reflection summary (600 words) summarising what you have achieved over the year and lessons you have learned for the future.

For further details, see https://www.sheffield.ac.uk/careers/jobs/placements.

Avoiding Collusion and Plagiarism

This has been extracted from the University’s Guidance for Students on the Use of Unfair Means, available from the SSiD web page at https://www.sheffield.ac.uk/ssid/unfair-means.
The University expects its graduates to have acquired certain attributes. Many of these relate to good academic practice.

Throughout your programme of studies at the University you will learn how to develop these skills and attributes. Your assessed work is the main way in which you demonstrate that you have acquired and can apply them. Using unfair means in the assessment process is dishonest and also means that you cannot demonstrate that you have acquired these essential academic skills and attributes.

What constitutes unfair means?

The basic principle underlying the preparation of any piece of academic work is that the work submitted must be your own work. Plagiarism, submitting bought or commissioned work, double submission (or self plagiarism), collusion and fabrication of results are not allowed because they violate this principle (see definitions below). Rules about these forms of cheating apply to all assessed and non-assessed work.

(i) **Plagiarism (either intentional or unintentional)** is using the ideas or work of another person (including experts and fellow or former students) and submitting them as your own. It is considered dishonest and unprofessional. Plagiarism may take the form of cutting and pasting, taking or closely paraphrasing ideas, passages, sections, sentences, paragraphs, drawings, graphs and other graphical material from books, articles, internet sites or any other source and submitting them for assessment without appropriate acknowledgement.

(ii) **Submitting bought or commissioned work** (for example from internet sites, essay "banks" or "mills") is an extremely serious form of plagiarism. This may take the form of buying or commissioning either the whole piece of work or part of it and implies a clear intention to deceive the examiners. The University also takes an extremely serious view of any student who sells, offers to sell or passes on their own assessed work to other students.

(iii) **Double submission (or self plagiarism)** is resubmitting previously submitted work on one or more occasions (without proper acknowledgement). This may take the form of copying either the whole piece of work or part of it. Normally credit will already have been given for this work.

(iv) **Collusion** is where two or more people work together to produce a piece of work, all or part of which is then submitted by each of them as their own individual work. This includes passing on work in any format to another student. Collusion does not occur where students involved in group work are encouraged to work together to produce a single piece of work as part of the assessment process.

(v) **Fabrication** is submitting work (for example, practical or laboratory work) any part of which is untrue, made up, falsified or fabricated in any way. This is regarded as fraudulent and dishonest.

How can I avoid the use of unfair means?

To avoid using unfair means, any work submitted must be your own and must not include the work of any other person, unless it is properly acknowledged and referenced.
As part of your programme of studies you will learn how to reference sources appropriately in order to avoid plagiarism. This is an essential skill that you will need throughout your University career and beyond. You should follow any guidance on the preparation of assessed work given by the academic department setting the assignment.

You are required to declare that all work submitted is entirely your own work. Many departments will ask you to attach a declaration form to all pieces of submitted work (including work submitted online). Your department will inform you how to do this.

If you have any concerns about appropriate academic practices or if you are experiencing any personal difficulties which are affecting your work, you should consult your personal tutor, supervisor or other member of staff involved.

The following websites provide additional information on referencing appropriately and avoiding unfair means:

The Library provides online information literacy skills help [https://www.sheffield.ac.uk/library/idlt](https://www.sheffield.ac.uk/library/idlt)

The Library also has information on reference management software [https://www.shef.ac.uk/library/refmant/refmant.html](https://www.shef.ac.uk/library/refmant/refmant.html)

The English Language Teaching Centre operates a Writing Advisory Service through which students can make individual appointments to discuss a piece of writing. This is available for all students, both native and non-native speakers of English. [https://www.shef.ac.uk/eltc/languagesupport/writingadvisory/index](https://www.shef.ac.uk/eltc/languagesupport/writingadvisory/index)

What happens if I use unfair means?

Any form of unfair means is treated as a serious academic offence and action may be taken under the Discipline Regulations. For a student registered on a professionally accredited programme of study, action may also be taken under the Fitness to Practise Regulations. Where unfair means is found to have been used, the University may impose penalties ranging from awarding no grade for the piece of work or failure in a PhD examination through to expulsion from the University in extremely serious cases.

Detection of Unfair Means

The University subscribes to a national plagiarism detection service which helps academic staff identify the original source of material submitted by students. This means that academic staff have access to specialist software that searches a database of reference material gathered from professional publications, student essay websites and other work submitted by students. It is also a resource which can help tutors and supervisors to advise students on ways of improving their referencing techniques. Your work is likely to be submitted to this service.

For further information, see [https://www.sheffield.ac.uk/ssid/complaints-and-appeals](https://www.sheffield.ac.uk/ssid/complaints-and-appeals).
Failure to Comply with Assessment Requirements

Failure to attend an examination without adequate reason will result in a grade of 0 being awarded. If you have good reasons to miss an exam due to circumstances beyond your control, you need to fill in an Extenuating Circumstances Form: https://www.sheffield.ac.uk/ssid/forms/circs. If the circumstances are medical and you are registered with the University Health Service (UHS), note what it says about filling in the electronic (or mobile app) version of the form and submitting it for UHS to add the documentation, and also that the doctor needs to have seen you while you are ill. (See the explanatory notes for this and more. The notes can be found here: https://www.sheffield.ac.uk/ssid/forms/circsnotes) In all other cases, please take the completed form and any other supporting documentation to SoMaS Reception in F10 as soon as you reasonably can. If you become ill during an exam, please tell an invigilator.

Excuses such as misreading the timetable or oversleeping are **not** acceptable as reasons for absence, but any student who misses an exam for such a reason should report to SoMaS Reception in F10 as soon as possible.

All unauthorized material (such as revision notes, books, etc) must be left outside the examination hall. This includes notes on scraps of paper. Students should ensure that their pockets are empty of such notes before entering the examination room. Students must also ensure that there are no written notes on their hands when they enter the examination hall and must not write on their hands during an examination. For further details of examination procedures, students should consult the regulations on examinations, which can be found via this link: https://www.sheffield.ac.uk/ssid/exams/rules/index

It is recommended that any student with personal circumstances continuing from the previous semester submits a new Extenuating Circumstances Form, to keep us up-to-date and to ensure that their case is not overlooked. Any student with a disability or chronic medical condition, for whom the Disability and Dyslexia Support Service has produced a learning support plan, need not keep filling in forms to inform us of their condition. In fact, disabilities and chronic medical conditions are not normally regarded as extenuating circumstances, the emphasis being on providing support to help students to do the best they can. However, it may be appropriate to submit an Extenuating Circumstances Form if there is a particular flare-up or complication at a time affecting exams.

Failure to hand in assessed coursework on time without good reason will result in the imposition of a penalty in accordance with the University’s Penalties Policy. Late submission of a major piece of assessed coursework, such as a project dissertation, will result in the deduction of 5% of the total mark awarded for each of the first 5 ‘University Working Days’ by which the submission is late; work submitted even later than that will receive a mark of 0. For pieces of assessed coursework that contribute only a small percentage of the overall assessment, the Faculty of Science has given the School approval to operate a policy of ‘zero tolerance’, under which any late submission receives a mark of 0.

Module leaders have the power to award dispensations in cases where the lateness was caused by certifiable medical problems or severe personal circumstances; requests for such dispensations should be made as soon as the problem is known, in writing or by e-mail to the module leader; students making such requests must also complete an ‘Extenuating Circumstances Form’ and hand it in at SoMaS Reception (F10).
Statement on Assessment Criteria

Typical examinations in SoMaS involve several questions, each of which will have components of at least some of the following types: (i) explanation of theory developed in the module; (ii) standard problems solvable using methods seen in the module; (iii) more difficult unseen problems requiring knowledge of the module but also requiring some original thought. Students’ scripts are assessed using a strict and detailed marking scheme, usually based on method and accuracy marks. The primary criterion is correctness, whether it be of calculation, method or explanation.

This produces a set of ‘raw marks’ which is then calibrated, using the judgement of the examiner, to the University’s 100-point reporting scale, which corresponds to degree classifications using the following rule:

\[
\begin{align*}
70–100 & : \text{Class I} \\
60–69 & : \text{Class II(i)} \\
50–59 & : \text{Class II(ii)} \\
45–49 & : \text{Class III} \\
40–44 & : \text{Pass.}
\end{align*}
\]

If an examiner feels that a mark of 30% on the exam is deserving of a pass, then 30% will be scaled to 40 on the University’s scale; there are similar points at each of the classification boundaries. The calibration is subjected to a central School scrutiny process involving the past record of each student who is registered for the module and for whom there are no abnormal circumstances.

Examination papers, including the past papers to which the students have access in advance, carry the distribution of marks between parts of questions.

The internal checker for each examination paper and the appropriate External Examiner are provided with copies of the module’s objectives/learning outcomes, and these are also distributed to students.

The School operates a scheme whereby marking is checked for accuracy. In addition, on each paper at Level 2 and above selected scripts, usually from the border bands between classifications, are sent to the appropriate External Examiner. Before the Final Year Examination Board Meeting, the External Examiners have the opportunity to look at all final year scripts, and generally look at those of candidates that are very close to borderlines, as well as other special cases.

All examination marking and all discussion at formal Examination Board Meetings is conducted anonymously, that is, students are identified only by their registration numbers.
Award of Degrees

In order to qualify for the award of a degree, students have to obtain a specified number of credits. Also, the ‘level’ of the credits is important. In what follows, ‘Level 3 modules’ refers to courses with a 3** or a 3**** code, normally (but not always) taken during Level 3, and ‘Level 4 modules’ refers to courses with a 4** or a 6**** code, normally (but not always) taken during Level 4. The pass mark for Level 3 modules is 40, and the pass mark for Level 4 modules is 50.

If you have NA results then you need to still be assessed for these modules as the regulations require you to have attempted (and received a numerical mark) for all 120 credits at each level.

In order to be awarded an honours degree of BSc, you must obtain at least 200 credits, of which at least 90 must be of modules of Level 3 or higher, out of the overall 240 credits possible on the second and third years combined.

This is a minimum requirement below which you cannot obtain an honours BSc degree: the granting of a pass degree (that is, without honours) to a student with fewer than 200 credits (or with fewer than 90 credits of modules of Level 3 or higher) is always at the discretion of the examiners, and requires the specific concurrence of the External Examiners. A minimum of 180 credits is required for this.

If you fail to be recommended for a degree, you may resit failed modules (i.e. where the result was a fail mark or ‘NC’ (Not Completed)) on a single occasion. Such resits will be capped at 40 (for level 3 modules)/50 (for level 4 modules) and you will only be eligible for a pass degree (without honours). We do not normally set resit papers at Levels 3 and 4 except when extenuating circumstances are involved, so you would normally have to wait for 12 months after the original examination.

Candidates for a BSc degree who have completed, and submitted themselves for assessment on, 120 credits at each of Levels 2 and 3 but have not been recommended for the award of a degree may enter for a subsequent examination for each failed module on one further occasion (subject to a maximum of two opportunities to sit any given module), but will only be eligible for the award of a pass degree.

In order to be awarded an honours degree of MMath, you must take 120 credits of Level 4 modules across Levels 3 and 4. You must obtain at least 320 credits, of which at least 90 must be Level 4 modules, out of the overall 360 credits possible on the second, third and fourth years combined, provided the Examiners recommend a class II(ii) degree or above. (Classification of honours degrees is discussed in the next subsection.) Candidates whom the Examiners would place in Class III will be recommended for the award of a BSc degree with honours; candidates whom the Examiners deem to be worthy of a pass shall be recommended for the award of a BSc pass degree.

In particular, in order to be awarded an MMath degree, you must pass at least 90 credits of Level 4 modules.

Candidates for an MMath degree who have completed, and submitted themselves for assessment on, 120 credits at each of Levels 2, 3 and 4 but have not been recommended for the award of a degree may enter for a subsequent examination for each module failed at Level 4 on one further occasion (subject to a maximum of two opportunities to sit any given module),
but will only be eligible for the award of a BSc pass degree.

**Classification of Honours Degrees**

Under the current Regulations, for each module you complete you will be awarded a mark on the University 100-point scale. This subsection describes the way that these marks contribute to the final degree classification.

The full details are available from the University’s General Regulations for First Degrees at [https://www.sheffield.ac.uk/media/14965/download](https://www.sheffield.ac.uk/media/14965/download) Here are the main points.

All your module marks (including any for which the mark is a fail) for years 2, 3 (and 4 if appropriate) are averaged, but Level 2 marks are given half the weight of Level 3 and Level 4 marks.

For students on the MMath Mathematics with Study in Europe or Year Abroad programmes or the MMath Mathematics with Spanish/French/German Language programmes, Level 2 and Level 3 marks are given half the weight given to Level 4 marks. (For the BSc Study in Europe and BSc Language programmes, marks for the year in Europe do not count towards the degree classification, although a pass for the year is required to remain on the programme.)

Then two calculations are made.

**Calculation 1** (the weighted mean grade) is made in accordance with the following principles:

- where a candidate’s weighted mean grade is of a value indicated in the first column, the outcome of Calculation 1 shall be the corresponding class indicated in the second column

  69.5 or higher : Class I
  59.5 or higher : Class II(i)
  49.5 or higher : Class II(ii)
  44.5 or higher : Class III
  39.5 or higher : Pass;

- where a candidate’s weighted mean grade falls within the band indicated in the first column, the outcome of Calculation 1 shall be the borderline to the corresponding class indicated in the second column

  68.0–69.4 : Class I
  58.0–59.4 : Class II(i)
  48.0–49.4 : Class II(ii)
  43.5–44.4 : Class III
  38.0–39.4 : Pass.

**Calculation 2** (the distribution of grades) is made in accordance with the following principles:

- where the best half of a candidate’s weighted grades are of a value indicated in the first column, the outcome of Calculation 2 shall be the corresponding class indicated in the second column

  68.0–69.4 : Class I
  58.0–59.4 : Class II(i)
  48.0–49.4 : Class II(ii)
  43.5–44.4 : Class III
  38.0–39.4 : Pass.
69.5 or higher : Class I
59.5 or higher : Class II(i)
49.5 or higher : Class II(ii)
44.5 or higher : Class III
39.5 or higher : Pass;

- where the best five twelfths of a candidate’s weighted grades are of a value indicated in the first column above, the outcome of Calculation 2 shall be the borderline to the corresponding class indicated in the second column above.

In recommending the class of degree to be awarded to each candidate, the Examiners shall take into account the outcomes of Calculations 1 and 2 in accordance with the following principles:

- where one Calculation places the candidate in one class and the other Calculation places the candidate in either the same class or the borderline to the same class, the candidate shall normally be recommended for the award of a degree of that class;

- where one Calculation places the candidate in one class, and the other Calculation places the candidate in the borderline to the class immediately above, the candidate shall normally be recommended for the award of a degree of the lower class;

- where one Calculation places the candidate in one class, and the other Calculation places the candidate in the class immediately below, the candidate shall be considered as being in the borderline to the higher class, and the class of the degree to be recommended by the Examiners shall normally correspond to the class indicated by the weighted mean of the grades at the final Level of study;

- where both Calculations place the candidate in the same borderline, the class of the degree to be recommended by the Examiners shall normally correspond to the class indicated by the weighted mean of the grades at the final Level of study;

- where one Calculation places the candidate in one class, or borderline to a class, and the other Calculation places the candidate in another class, or borderline to a class, neither immediately above nor below, the Examiners shall recommend the classification which, having regard to all the evidence before them, best reflects the overall performance of the candidate.

Note that the Examiners are free to vary from the formal rules for any candidate where there is strong evidence to support such a decision. In consideration of such evidence, the Examiners will seek guidance from the School’s External Examiners. Also, if a candidate is awarded a classified degree (I, II(i), II(ii), or III) then the degree is an honours degree irrespective of whether the candidate has any failed modules.

There is a University appeals procedure, full details of which are displayed on the student notice boards listed later in this handbook. They may be also found on the web at https://www.sheffield.ac.uk/ssid/complaints-and-appeals.

Transcripts

After graduation, you may wish to obtain a transcript of your detailed module results to show prospective employers. For details see https://www.shef.ac.uk/ssid/transcript. Note
that there is a small charge, which increases more than 12 months after graduation.
Prizes

The following prizes may be awarded to Level 3 and Level 4 students.

David Burley Prize in Applied Mathematics

This prize was established in 2000 and named in honour of Dr D M Burley, former Head of the Department of Applied Mathematics and a member of staff from 1960 to 1995.

1. Frequency of award: One annually.
2. Value of prize: £100.
3. Eligible candidates: Students taking a significant proportion of Level 3 or 4 units in Applied Mathematics.
4. Assessor: The Head of School.

Sir Edward Collingwood Prizes in Probability and Statistics

This prize was founded in 1970 by the Applied Probability Trust in memory of Sir Edward Collingwood, who was Chairman of the Trust from its inception in 1963 to 1970, and President of the London Mathematical Society in 1970.

1. Frequency of award: Two annually.
2. Value of prizes: £60 each.
3. Eligible candidates: (a) Students who have completed two years of a programme of study containing, in the opinion of the Head of School, a substantial amount of Probability and/or Statistics. (b) Students who are taking the Final Examination for the programmes of study in Mathematics and Statistics.
4. Assessor: The Head of School.
5. Criteria for assessment: The best overall performance in Probability and/or Statistics (not necessarily the highest marks in any examination).

T M Flett Prizes in Pure Mathematics

These prizes were founded in 1977 from subscriptions in memory of Professor T M Flett, member of staff of the Department of Pure Mathematics from 1967 to 1976.

1. Frequency of award: Two annually.
2. Value of prizes: £85
3. Eligible candidates: Students who are taking the Final Examination for a programme of study in which the Pure Mathematics component constitutes at least one half of the Level 3 course.
4. Assessor: The Head of School.

5. Criteria for assessment: The appropriate examination considered in conjunction with coursework carried out during the year.

**Wendy Wright Prize in Probability and Statistics**

This prize was endowed by Miss Hilda Davies on her retirement from the Department of Probability and Statistics in 1979 and named at her request in memory of Mrs Wendy M Wright, a graduate of the University and former Research Assistant in Statistics.

1. Frequency of award: One annually.
2. Value of prize: £100.
3. Eligible candidates: Final year undergraduates on a programme of study involving a substantial number of Statistics courses.
4. Assessor: The Head of School.
5. Criteria for assessment: Performance in Level 3 or Level 4 practical and applied project work in Probability and Statistics.

**The Institute of Mathematics and its Applications Prize**

This prize was established by the Institute of Mathematics and its Applications (IMA). The IMA is the UK’s learned and professional society for mathematicians and its applications. It promotes mathematics research, education and careers, and the use of mathematics in business, industry and commerce.

1. Frequency of award: Two annually.
3. Eligible candidates: Final year students in the School of Mathematics and Statistics.
4. Assessor: The Head of School.
4 Help, Guidance and Information

Personal Tutors

The personal tutorial system operates for the rest of your course. The present arrangements are that students normally continue with the same personal tutor as in the second year. If you envisage any problem with this then please see the Senior Tutor; it is possible for you to request a change of personal tutor. Third- and fourth-year students should go to see their tutors each semester, at the beginning of Semester 1 and in Semester 2 when the Semester 1 examination results have been published. However, questions about work concerning particular modules should generally be put to the lecturers concerned. All students are encouraged to keep in touch with their tutors who are then in a good position to act as referees when the time for job applications arrives.

There is in addition a Tutor for Women Students, who is available to discuss problems of a more personal or confidential nature. The Senior Tutor currently acts as a Tutor for Men Students.

If you have any difficulty in contacting your personal tutor, or he or she is unable to solve any problem or answer any query, then you can approach the Senior Tutor or other designated staff members (see the list at http://www.maths.dept.shef.ac.uk/maths/contact.html).

Please make sure that your home address is correct on MUSE before you leave at the end of Semester 2. You will have the same University e-mail address in 2021–2022 as this year. You should make sure your tutor knows your e-mail address, and you should check for e-mail messages when you return to Sheffield in September.

Higher Education Achievement Report

The University has introduced a new kind of degree transcript for all new undergraduate students: the Higher Education Achievement Report or ‘HEAR’. The HEAR provides a comprehensive record of your university achievements and it recognises your extra-curricular achievements as well as your academic learning. It can be used to help you identify your strengths, and to plan how to build on these to achieve your goals, and it provides employers and others with evidence of your university learning and experiences.

Find out more by visiting the HEAR website https://www.sheffield.ac.uk/ssid/hear

Library

The University Library provides 24-hour access to study space, a huge range of books and online information (including online journals and ebooks) as well as advices to help you find and use information effectively. You will find all the information you need to get started on the library webpages.

Places to study

There are four different library sites where you can go to study, find reading for your course, and get advice on finding, organising and referencing information. You will need to bring your
Ucard with you to get into the library, borrow books and to use the printers and copiers. Remember to ask a member of staff if you need anything.

- The Information Commons (IC) is open 24 hours a day. You should find most of your recommended books here. Visit the Information Desk on level 1 for help using the library, finding materials for your course, or for help with your computer or laptop.

- The Diamond is open 24 hours a day, and has four floors of study space. Visit the top floor (Level 4) to speak to Library and CiCS staff at the Information Desk or to use the collection of reference books.

- Western Bank Library is a good place for quiet study or revision, with a large reading room overlooking Weston Park.

- The Health Sciences Library, based in the Medical School at the Royal Hallamshire Hospital has books and journals covering medicine, dentistry and health.

Visit the learning spaces page (https://www.sheffield.ac.uk/learning-spaces) to check how busy each library is before you go and see the other study spaces available across campus.

StarPlus is the Library’s online search tool. Use it to find books and ebooks, online journals, articles, and other information available through the Library. Log in to MUSE and open StarPlus from the link in the ‘My Services’ menu. Use StarPlus to:

- find reading for your course or research for an assignment
- request something that is out on loan; the Library will let you know when it is ready to collect
- save the details of useful books, journals and articles so you can refer to them later (useful when referencing)

Searching the scientific literature

Web of Science and Scopus and arXiv.org can be used to search the journal literature and explore scientific research. To find other useful databases, visit the Maths and Statistics library guide, or contact your librarian.

Developing your skills: visit the Library’s study web pages for advice on:

- how to find information for your study and assignments,
- how to cite/reference correctly, and avoid plagiarism
- finding details of optional workshops to support your learning

Help and support

- For general enquiries, contact Library Help or speak to a member of library staff.
- Helen Moore is the librarian for Science – you can contact him for advice on finding reading for your studies or with any other questions you have relating to library support for your course (H.Moore@sheffield.ac.uk, 01142227309, book an appointment)
• If you would like to borrow a book or read an article that the Library does not have, complete the InterLibrary Request form (available from the ‘My Services’ menu in MUSE) and we will try to get it for you from the British Library. If you would like to suggest a book for the Library to buy use the book recommendation form.

Student Advice Centre, SSiD, Counselling Service, University Health Service

The Student Advice Centre (https://www.sheffield.ac.uk/ssid/contacts/advice) and Student Services Information Desk (SSiD, https://www.sheffield.ac.uk/ssid) provide assistance on a wide range of problems. Specifically, they provide advice on housing, finance, problems about harassment, and help to international students; they also help with academic matters. The Counselling Service (https://www.sheffield.ac.uk/ssid/counselling) and the University Health Service (https://www.sheffield.ac.uk/ssid/health-service) are also there to help you, and help with mental health problems can be found from https://www.sheffield.ac.uk/ssid/health-service/conditions/mental-health; strict confidence is always observed.

iSheffield

Lots of information can be found from the iSheffield mobile app (see https://www.sheffield.ac.uk/it-services/isheffield). In particular your timetable should be there, and near the start of semester it should have the correct tutorial times and rooms for you.

301

301: Student Skills and Development Centre offers a range of services for all students:

• Maths and Statistics Help
• Academic Skills workshops
• Study Skills Sessions
• Specialist Dyslexia/SpLD tutorial Service
• Languages for All programme
• Writing Advisory Service

301 also offers an Academic Skills Certificate which can be included in your Higher Education Achievement Report (HEAR). For more details see https://www.sheffield.ac.uk/ssid/301/services.

The English Language Teaching Centre (ELTC)

If you need help with your English language then this can be provided by the ELTC. For further details see https://www.sheffield.ac.uk/eltc.
What to do if things are not going right

Obviously, the School hopes that all of you will enjoy your degrees and your time in Sheffield. But we know that, for various reasons, some of you may have problems which may affect your studies, and that at times there are things which need to take precedence over your work.

Your first port of call within SoMaS should be your Personal Tutor, or the Senior Tutor. We may not be qualified to give you the help that you may need, but the University will have people who can, and your tutor can direct you to the appropriate help. There is a Student Advice Centre next to the Student Services Information Desk in the Student Union, who have a lot of leaflets and can also help advise you. See https://www.sheffield.ac.uk/ssid/sos for a range of services offered by the University.

For any issues that affect assessment, you need to complete an Extenuating Circumstances Form – see page 12.

If issues persist, or are very serious, you may want to take Leave of Absence, and return at a later date. For this, you will need to complete a Change of Status Form for Leave of Absence. Some issues are discussed at https://www.shef.ac.uk/ssid/change-of-status/leave; for example, there are likely to be some financial considerations, and overseas students may face visa issues. If medical issues are the cause of the request, you will need to satisfy the University that you have recovered sufficiently before you return. Any forms which affect your “status” will require the signature of the Senior Tutor; they should then be handed in at SoMaS Reception (F10) so that we can make a copy, before being sent to Taught Programmes Office.

All forms can be downloaded from https://www.sheffield.ac.uk/ssid/forms; paper copies of all these are also available from SoMaS Reception (F10).

Nightline

Nightline (see https://www.sheffieldnightline.co.uk) is the University of Sheffield’s confidential listening and information telephone service. It is run by trained student volunteers, and operates from 8.00pm until 8.00am every night during term time. It offers students everything from the phone number of a twenty-four hour taxi company, to examination dates, times and locations, and information about many issues that can be encountered within student life. It provides a vital support network for all students, so whatever you need to say, Nightline is listening, and the service can be called free from phones in halls of residence. If you think you would like to volunteer for Nightline, contact sunl@sheffield.ac.uk for more information.

The Careers Service

The Careers Service (whose web page is at https://www.shef.ac.uk/careers/) offers an excellent provision, backed up with a wealth of experience, to help students decide on a career and to find employment after graduation. You could also talk to the School’s Careers Officer, listed on http://www.maths.dept.shef.ac.uk/maths/contact.html.

Making good career decisions will involve you in thinking about your qualities and inclinations. The Careers Service provide resources on career planning, CV writing, job seeking, interview skills, and much else. They also organise an extensive programme of careers events, which
provides valuable opportunities to meet prospective graduate employers, and find out what skills they are looking for.

Graduates from our degrees go on to a wide range of careers. Many go on to careers for which a mathematical degree is very important; others go on to careers where degree-level education is important, though not necessarily using mathematical skills. Mathematics graduates have a strong range of transferable skills, including excellent numeracy and analytical problem solving skills. Your degrees often make use of computer packages, and these IT skills are often adaptable to IT requirements of employers. Employers also value highly the ability to communicate mathematical ideas to lay audiences.

A number of our graduates have interest in teaching; the Postgraduate Diploma in Education (PGDE) is a common qualification, and is offered in mathematics by the University of Sheffield (and many other universities). It is administered by the School of Education, and you should contact them for further information. Other graduates go on to more specialised postgraduate qualifications, including our own MSc in Statistics and MSc in Mathematics.

Students are strongly advised to make use of the wide range of resources that the Careers Service has to offer. The Careers Service (https://www.sheffield.ac.uk/careers) is located at 241 Glossop Road in Edgar Allen House. There is also a Student Jobshop in the Student Union.

The School of Mathematics and Statistics runs MAS279 (Career Development Skills), a dedicated careers module for Mathematics students, which is available to students on a number of our single honours programmes.

**The Staff-Student Forum**

Nominations for the Staff-Student Forum will first be requested in the Spring Semester, for positions in the following academic year. Please think about the possibility of serving on the Forum. It will give you an opportunity to have a role in the organisation and management of factors influencing student life in the School of Mathematics and Statistics. The Forum usually meets twice a semester. A number of student members serve as student representatives on the School Teaching Committee.

Issues may be raised with forum members at any time. You can find more information at https://www.sheffield.ac.uk/maths/current/representation, where you can also find a feedback form which goes to SoMaS Reception and eventually to the Director of Teaching.

There are further opportunities for student representation within the Faculty of Science.

**Study room**

I19 Hicks, on the 5th floor, is a study room for undergraduates. It has plenty of space, tables and chairs and a whiteboard, and is intended for quiet study. It is somewhere you can go to make productive use of time in between lectures and tutorials, and might be especially useful if you are in the Hicks Building and you do not want to use time going to the Information Commons, Library, Student Union or wherever. There is a smaller room, the Barry Jackson Room, at the back of the ground floor of the building, just before Lecture Rooms 3 and 4.
This is also somewhere you can go to sit down, but with maybe less of an expectation of peace and quiet, more a social space.

**Voluntary work**

The University encourages its students to consider undertaking some voluntary work. The text below has been provided by the Manager of Sheffield Volunteering, which is based in the Students’ Union.

‘Volunteering is a great way to get to know the city and its people. You can gain career-related experience or simply volunteer for something that appeals.

‘You can do something just for a day or give a couple of hours each week or fortnight. It’s really flexible and you won’t be asked to help during exams or vacations.

‘Choose from over 100 options — in student neighbourhoods and the city centre. Alternatively, we can help you to develop your own volunteer project involving other students and benefiting the wider community.

‘Our staff can help you to find something that’s right for you. Training and out-of-pocket expenses are provided too.

‘Set yourself apart. Visit [https://www.sheffield.ac.uk/experience/volunteer](https://www.sheffield.ac.uk/experience/volunteer) or see us in the Source (Level 3, Union Building).’

**Where else to find Information**

Information will be displayed in the Hicks Building on the notice boards outside F10.

Urgent messages will be displayed in the Entrance Foyer, or sent by e-mail. Please check notice boards and your e-mail regularly.

**Office-holders in the School**

A list of the members of staff who currently hold various offices in the School of Mathematics and Statistics can be found at [http://www.maths.dept.shef.ac.uk/maths/contact.html](http://www.maths.dept.shef.ac.uk/maths/contact.html).
Official University Information for Students on the Web

General regulations (including degree regulations) https://www.shef.ac.uk/calendar/
General Regulations relating to Academic Appeals https://www.sheffield.ac.uk/media/14976/download

Regulations and procedures for grievances and complaints, Appeals https://www.sheffield.ac.uk/ssid/complaints-and-appeals

Specific SoMaS programme regulations https://www.shef.ac.uk/calendar/regs

SSiD web pages (including exam information, fees, finance, etc.) https://www.shef.ac.uk/ssid/

IT information for students https://www.sheffield.ac.uk/it-services/students

Student Rights and Responsibilities https://www.sheffield.ac.uk/ssid/ourcommitment/rights

Help and support for students https://www.shef.ac.uk/ssid/sos/

Disability and dyslexia support https://www.sheffield.ac.uk/ssid/disability

Essential guide for mature students https://www.sheffield.ac.uk/ssid/mature-students

Information for international students https://www.shef.ac.uk/ssid/international/

Details of programme regulations https://www.sheffield.ac.uk/programmeregulationsfinder/
5 Health and Safety

Smoking

Students are reminded that smoking is prohibited on all University premises – this includes the area under the canopy at the main entrance to the Hicks Building. In addition, we request that you refrain from smoking on the steps immediately outside the Hicks Building.

First Aid

First Aid boxes are available in SoMaS Reception (Room F10) and the Porters Lodge (Hicks Foyer, D Floor). Lists of qualified first-aiders can be found outside, or near to, these locations.

Fire Alarm

If the fire alarm sounds in the Hicks Building, please proceed calmly to the nearest exit and assemble in the designated area (on the concourse, underneath the road bridge). Do not use lifts. Do not re-enter the building until you have been told that it is safe to do so by a fire officer. Weekly fire alarm tests are performed in all University buildings at varying times depending on the building. On these occasions the bell rings for approximately 15-30 seconds and no action is required unless the alarm sounds continuously for longer than approximately 30 seconds. The test will take place in the Hicks Building on Wednesdays at about 9.30.
6 Information on Mathematics and Statistics Courses

The Aims and Learning Outcomes of the Degree Programmes

The mission of the School of Mathematics and Statistics is

- to conduct high quality research in mathematics and statistics;
- to provide an excellent and inspiring education for students;
- to support, to promote and to increase the impact of our disciplines;
- to be a research-led school that maintains high standards in all activities.

Aims

For all the School’s undergraduate programmes, the aims are:

- to provide an intellectual environment conducive to learning;
- to prepare students for careers which use their mathematical and/or statistical training;
- to provide teaching which is informed and inspired by the research and scholarship of staff;
- to provide students with assessments of their achievements over a range of mathematical and statistical skills, and to identify and support academic excellence.

There are also additional aims for particular programmes.

- In all its first degrees the School aims to provide programmes with internal choice to accommodate the diversity of students’ interests and abilities.
- In its single honours degrees, the School aims to provide a programme in which students may choose either to specialise in one mathematical discipline (Pure Mathematics, Applied Mathematics\(^1\), Probability and Statistics) or to follow a more balanced programme incorporating two or all three of these disciplines.
- In all MMath programmes, the School aims to prepare students for progression to a research degree in one of the three mathematical disciplines or for careers in which the use of Mathematics is central.
- In its single honours programmes with Study in Europe and its programmes with Spanish, French or German Language, the School aims to offer students the opportunity to study Mathematics and Statistics in another European country.
- The MMath/BSc programmes with a named language also aim to provide language instruction beyond that needed to study Mathematics and Statistics abroad, giving students the opportunity to acquire all-round fluency in the language.
- In its programme Mathematics with a Year Abroad, the School aims to give students the opportunity to benefit from the experience of studying in a different educational culture.

\(^1\)Students on the MMath/BSc Mathematics with Spanish/French/German Language programmes are not permitted to take any Applied Mathematics module.
In its Financial Mathematics programme, the School aims to provide students with a suitable mathematical and financial background to enter careers in the financial services industry.

**Learning Outcomes**

In line with the requirements of HEFCE’s Teaching Quality Information initiative, the University has introduced programme specifications for undergraduate and postgraduate taught programmes to provide clear and explicit information for existing and potential students so that they can make informed choices about their studies. In addition to the Aims of the School’s undergraduate programmes listed above, there are Learning Outcomes that students are expected to have developed upon successful completion of the programme and achievement of which will usually have been demonstrated via the assessment process. These differ for each degree programme offered; students may consult the latest versions at [https://www.shef.ac.uk/calendar/progspec](https://www.shef.ac.uk/calendar/progspec).

**Module Questionnaires - the ‘Tell US’ System**

The university has introduced a central system for module questionnaires. It is called Tell US and is being used by all departments in the university and replaces our old system in the School of Mathematics and Statistics. Students are strongly encouraged to provide feedback via the system for every module they take. You can access the questionnaires via this link [https://tellus.shef.ac.uk/tellus/](https://tellus.shef.ac.uk/tellus/). Instructions will be issued every semester. You are likely to get reminders from the centre of the university when the questionnaires are open.

These questionnaires are important to the School. This is your formal opportunity to give your view on aspects of the course – you can also give comments informally via your Personal Tutor, the Staff-Student Forum, to the lecturer directly, etc., and this is also appreciated.

We are always keen to hear ways to improve our teaching and your learning experience. Considered and thoughtful feedback can provide an extremely helpful input into the School’s teaching.

In the same way that receiving a piece of marked work with just a mark out of 10 is not as useful as comments showing how you can improve, we would like to encourage you to be specific and constructive in your questionnaire responses. Reasoned and constructive comments you make on modules can be very helpful, both to the individual lecturer concerned, and to the School, so that we can spread good practice.

Lecturers are human beings with feelings, just like students, and if you feel the need to be critical of aspects of a module, please try to offer criticism in a sensitive way. It is always good to read positive comments as well as critical ones, so if you feel that a lecturer is doing something well, please let them know!

The questionnaires and comments are considered by members of the Staff-Student Forum, and by the School’s Teaching Committee. Past comments have led to changes in School procedures, as well as to alterations in course content and practice of lecturers. They also form a valuable input to the annual appraisal of staff. Your considered feedback plays a valuable part in improving our teaching.
Degree Regulations

Full details of these Regulations are available on the web, as described in the section entitled ‘Official University Information for Students on the Web’ on p.26. However, at the time of publication of this handbook, the Regulations on the web may be for 2020–2021 rather than 2021–2022. In particular, their lists of modules may reflect availability in 2020–2021 rather than in 2021–2022.

You are reminded that to be eligible to enter Level 3 of the degree of MMath you must normally have obtained 120 credits at Level 2 with an average of at least 59.5. Candidates for the MMath Mathematics with Year Abroad who fail to achieve the required average in Level 2 may be able to transfer to BSc in Mathematics. Anyone considering this should consult the Programme Leader for Study Abroad. Candidates for the MMath Mathematics with Study in Europe, or for the MMath Mathematics with Spanish/French/German Language, who fail to achieve the required average in Level 2 may be able to transfer to the corresponding BSc rather than the ordinary BSc. Anyone considering this should consult the Programme Leader for European Programmes.

Details of SoMaS modules can be found at the end of this handbook. For modules from outside SoMaS, please consult the relevant department for information.

In what follows, the term ‘Level 3 module’ refers to the modules listed later in this booklet which have 3** or 3**** codes and the term ‘Level 4 module’ refers to those which have 4** or 6**** codes. Broadly speaking, you would expect to do Level 3 modules in your third year and Level 4 modules (if you are taking the MMath) in your fourth year; but exceptions are allowed, as detailed below. Remember that the pass mark for Level 3 modules is 40, and the pass mark for Level 4 modules is 50.

Specific degree regulations

BSc Mathematics (MASU01) Year 3, BSc Mathematics with Study in Europe (MASU11) Year 4

You must take modules to the value of 120 credits from the Level 3 modules listed below:

- **MAS301** Group Project 10 credits
- **MAS302** Undergraduate Ambassador Scheme in Mathematics 20 credits
- **MAS310** Continuum Mechanics 10 credits
- **MAS31001** Generalised Linear Models 10 credits
- **MAS314** Introduction to Relativity 10 credits
- **MAS315** Waves 10 credits
- **MAS316** Mathematical Modelling of Natural Systems 10 credits
- **MAS320** Fluid Mechanics I 10 credits
- **MAS322** Operations Research 10 credits
- **MAS324** Quantum Theory 10 credits
- **MAS325** Mathematical Methods 10 credits
- **MAS330** Topics in Number Theory 10 credits
- **MAS331** Metric Spaces 10 credits
- **MAS332** Complex Analysis 10 credits
- **MAS333** Fields 10 credits
- **MAS334** Combinatorics 10 credits
(a) BSc Mathematics students may replace up to 30 credits of these Level 3 modules by modules from the list:

- MAS423 Advanced Operations Research 10 credits
- MAS438 Fields 10 credits
- MAS442 Galois Theory 10 credits
- MAS452 Stochastic Processes and Finance 20 credits

(b) In addition to (a), BSc Mathematics students may replace up to 20 credits of Level 3 modules by the following optional modules if they are not taking MAS302 (Undergraduate Ambassador Scheme in Mathematics) (see the section on additional optional modules on p.6 for details of the conditions that apply).

- APS31006 Human Planet 10 credits
- APS341 Evolution of Terrestrial Ecosystems 10 credits
- APS344 Topics in Evolutionary Genetics 10 credits
- APS346 Sustainable Agro-Ecosystems 10 credits
- COM3110 Text Processing 10 credits
- COM3240 Adaptive Intelligence 10 credits
- COM3502 Speech Processing 10 credits
- EDU309 Globalising Education 20 credits
- PHI372 Pain, Pleasure, and Emotions 20 credits
- PHY327 History of Astronomy 10 credits
- PSY358 Current Controversies in the Psychology of Addition 10 credits

Languages for All modules

For details of the Languages for All modules, see https://www.sheffield.ac.uk/languages/lfa/modules.
(c) BSc Mathematics with Study in Europe students may replace *up to 20 credits* of the Level 3 mathematics modules listed above by appropriate MLT modules.

The options (a) above are, however, subject to the consent of the School (which is given when your module choice form is approved). In general, to be permitted to take these modules you will need to have scored an average of at least 60 at Level 2 (or in the Level 2 January examinations, if only those results are available). You will also have to obtain satisfactory grades in the necessary prerequisite modules.

You *must not* choose modules to the value of more than *70 credits* in any semester. (You are advised to avoid taking 70 credits in the second semester.)

**BSc Mathematics and Statistics (MASU38) Year 3**

If you are interested in switching to this degree please talk to the Senior Tutor about it. In particular you need to be sure that you have taken the correct modules at previous Levels.

You must take:

<table>
<thead>
<tr>
<th>Module Code</th>
<th>Module Name</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS360</td>
<td>Practical and Applied Statistics</td>
<td>20</td>
</tr>
<tr>
<td>MAS361</td>
<td>Medical Statistics</td>
<td>10</td>
</tr>
<tr>
<td>MAS364</td>
<td>Bayesian Statistics</td>
<td>10</td>
</tr>
<tr>
<td>MAS370</td>
<td>Sampling Theory and Design of Experiments</td>
<td>10</td>
</tr>
<tr>
<td>MAS371</td>
<td>Applied Probability</td>
<td>10</td>
</tr>
</tbody>
</table>

and modules to the value of *60 credits* from the Level 3 modules listed below:

<table>
<thead>
<tr>
<th>Module Code</th>
<th>Module Name</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS302</td>
<td>Undergraduate Ambassador Scheme in Mathematics</td>
<td>20</td>
</tr>
<tr>
<td>MAS310</td>
<td>Continuum Mechanics</td>
<td>10</td>
</tr>
<tr>
<td>MAS31001</td>
<td>Generalised linear models</td>
<td>10</td>
</tr>
<tr>
<td>MAS314</td>
<td>Introduction to Relativity</td>
<td>10</td>
</tr>
<tr>
<td>MAS315</td>
<td>Waves</td>
<td>10</td>
</tr>
<tr>
<td>MAS316</td>
<td>Mathematical Modelling of Natural Systems</td>
<td>10</td>
</tr>
<tr>
<td>MAS320</td>
<td>Fluid Mechanics I</td>
<td>10</td>
</tr>
<tr>
<td>MAS322</td>
<td>Operations Research</td>
<td>10</td>
</tr>
<tr>
<td>MAS324</td>
<td>Quantum Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS325</td>
<td>Mathematical Methods</td>
<td>10</td>
</tr>
<tr>
<td>MAS330</td>
<td>Topics in Number Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS331</td>
<td>Metric Spaces</td>
<td>10</td>
</tr>
<tr>
<td>MAS332</td>
<td>Complex Analysis</td>
<td>10</td>
</tr>
<tr>
<td>MAS333</td>
<td>Fields</td>
<td>10</td>
</tr>
<tr>
<td>MAS334</td>
<td>Combinatorics</td>
<td>10</td>
</tr>
<tr>
<td>MAS336</td>
<td>Differential Geometry</td>
<td>10</td>
</tr>
<tr>
<td>MAS341</td>
<td>Graph Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS343</td>
<td>History of Mathematics</td>
<td>10</td>
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<tr>
<td>MAS344</td>
<td>Knots and Surfaces</td>
<td>10</td>
</tr>
<tr>
<td>MAS345</td>
<td>Codes and Cryptography</td>
<td>10</td>
</tr>
<tr>
<td>MAS346</td>
<td>Groups and Symmetry</td>
<td>10</td>
</tr>
</tbody>
</table>
(a) **Up to 30 credits** of the latter modules may be replaced by modules from the list:

- **MAS423** Advanced Operations Research 10 credits
- **MAS438** Fields 10 credits
- **MAS442** Galois Theory 10 credits
- **MAS451** Measure and Probability 10 credits
- **MAS452** Stochastic Processes and Finance 20 credits

(b) In addition to (a), students may replace **up to 20 credits** of the Level 3 optional modules above by some the modules in the following list if they are not taking **MAS302** (Undergraduate Ambassador Scheme in Mathematics) (see the section on additional optional modules on p.6 for details of the conditions that apply).

- **APS31006** Human Planet 10 credits
- **APS341** Evolution of Terrestrial Ecosystems 10 credits
- **APS344** Topics in Evolutionary Genetics 10 credits
- **APS346** Sustainable Agro-Ecosystems 10 credits
- **COM3110** Text Processing 10 credits
- **COM3240** Adaptive Intelligence 10 credits
- **COM3502** Speech Processing 10 credits
- **EDU309** Globalising Education 20 credits
- **PHI372** Pain, Pleasure, and Emotions 20 credits
- **PHY327** History of Astronomy 10 credits
- **PSY358** Current Controversies in the Psychology of Addition 10 credits

Languages for All modules

For details of the Languages for All modules, see https://www.sheffield.ac.uk/languages/lfa/modules.

The options (a) above are, however, subject to the consent of the School (which is given when your module choice form is approved). In general, to be permitted to take these modules you will need to have scored an average of at least 60 at Level 2 (or in the Level 2 January examinations, if only those results are available). You will also have to obtain satisfactory grades in the necessary prerequisite modules.

**MMath Mathematics and Statistics (MASU39) Year 3**

If you are interested in switching to this degree please talk to the Senior Tutor about it. In particular you need to be sure that you have taken the correct modules at previous Levels.
You must take:

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS360</td>
<td>Practical and Applied Statistics</td>
<td>20</td>
</tr>
<tr>
<td>MAS361</td>
<td>Medical Statistics</td>
<td>10</td>
</tr>
<tr>
<td>MAS370</td>
<td>Sampling Theory and Design of Experiments</td>
<td>10</td>
</tr>
<tr>
<td>MAS371</td>
<td>Applied Probability</td>
<td>10</td>
</tr>
<tr>
<td>MAS372</td>
<td>Time Series</td>
<td>10</td>
</tr>
</tbody>
</table>

and a minimum of 40 and a maximum of 60 credits from the Level 3 modules listed below:

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS310</td>
<td>Continuum Mechanics</td>
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<tr>
<td>MAS314</td>
<td>Introduction to Relativity</td>
<td>10</td>
</tr>
<tr>
<td>MAS315</td>
<td>Waves</td>
<td>10</td>
</tr>
<tr>
<td>MAS316</td>
<td>Mathematical Modelling of Natural Systems</td>
<td>10</td>
</tr>
<tr>
<td>MAS320</td>
<td>Fluid Mechanics I</td>
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<tr>
<td>MAS322</td>
<td>Operations Research</td>
<td>10</td>
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<tr>
<td>MAS324</td>
<td>Quantum Theory</td>
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<td>Mathematical Methods</td>
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<td>MAS330</td>
<td>Topics in Number Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS331</td>
<td>Metric Spaces</td>
<td>10</td>
</tr>
<tr>
<td>MAS332</td>
<td>Complex Analysis</td>
<td>10</td>
</tr>
<tr>
<td>MAS333</td>
<td>Fields</td>
<td>10</td>
</tr>
<tr>
<td>MAS334</td>
<td>Combinatorics</td>
<td>10</td>
</tr>
<tr>
<td>MAS336</td>
<td>Differential Geometry</td>
<td>10</td>
</tr>
<tr>
<td>MAS341</td>
<td>Graph Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS343</td>
<td>History of Mathematics</td>
<td>10</td>
</tr>
<tr>
<td>MAS344</td>
<td>Knots and Surfaces</td>
<td>10</td>
</tr>
<tr>
<td>MAS345</td>
<td>Codes and Cryptography</td>
<td>10</td>
</tr>
<tr>
<td>MAS346</td>
<td>Groups and Symmetry</td>
<td>10</td>
</tr>
<tr>
<td>MAS348</td>
<td>Game Theory</td>
<td>10</td>
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<tr>
<td>MAS350</td>
<td>Measure and Probability</td>
<td>10</td>
</tr>
<tr>
<td>MAS352</td>
<td>Stochastic Processes and Finance</td>
<td>20</td>
</tr>
<tr>
<td>MAS362</td>
<td>Financial Mathematics</td>
<td>10</td>
</tr>
<tr>
<td>MAS377</td>
<td>Mathematical Biology</td>
<td>10</td>
</tr>
</tbody>
</table>

and up to 20 credits of modules from this list:

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MAS302</td>
<td>Undergraduate Ambassadors Scheme in Mathematics</td>
<td>20</td>
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<td>MAS411</td>
<td>Topics in Advanced Fluid Mechanics</td>
<td>20</td>
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<td>MAS413</td>
<td>Analytical Dynamics and Classical Field Theory</td>
<td>20</td>
</tr>
<tr>
<td>MAS414</td>
<td>Mathematical Modelling of Natural Systems (Advanced)</td>
<td>10</td>
</tr>
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<td>MAS420</td>
<td>Signal Processing</td>
<td>10</td>
</tr>
<tr>
<td>MAS422</td>
<td>Magnetohydrodynamics</td>
<td>10</td>
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<tr>
<td>MAS423</td>
<td>Advanced Operations Research</td>
<td>10</td>
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<tr>
<td>MAS430</td>
<td>Analytic Number Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS435</td>
<td>Algebraic Topology</td>
<td>20</td>
</tr>
<tr>
<td>MAS436</td>
<td>Functional Analysis</td>
<td>20</td>
</tr>
<tr>
<td>MAS438</td>
<td>Fields</td>
<td>10</td>
</tr>
<tr>
<td>MAS439</td>
<td>Commutative Algebra and Algebraic Geometry</td>
<td>20</td>
</tr>
<tr>
<td>Code</td>
<td>Module</td>
<td>Credits</td>
</tr>
<tr>
<td>--------</td>
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<td>---------</td>
</tr>
<tr>
<td>MAS442</td>
<td>Galois Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS451</td>
<td>Measure and Probability</td>
<td>10</td>
</tr>
<tr>
<td>MAS452</td>
<td>Stochastic Processes and Finance</td>
<td>20</td>
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<tr>
<td>MAS462</td>
<td>Financial Mathematics</td>
<td>10</td>
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<tr>
<td>APS31006</td>
<td>Human Planet</td>
<td>10</td>
</tr>
<tr>
<td>APS341</td>
<td>Evolution of Terrestrial Ecosystems</td>
<td>10</td>
</tr>
<tr>
<td>APS344</td>
<td>Topics in Evolutionary Genetics</td>
<td>10</td>
</tr>
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<td>APS346</td>
<td>Sustainable Agro-Ecosystems</td>
<td>10</td>
</tr>
<tr>
<td>COM3110</td>
<td>Text Processing</td>
<td>10</td>
</tr>
<tr>
<td>COM3240</td>
<td>Adaptive Intelligence</td>
<td>10</td>
</tr>
<tr>
<td>COM3502</td>
<td>Speech Processing</td>
<td>10</td>
</tr>
<tr>
<td>EDU309</td>
<td>Globalising Education</td>
<td>20</td>
</tr>
<tr>
<td>PHI372</td>
<td>Pain, Pleasure, and Emotions</td>
<td>20</td>
</tr>
<tr>
<td>PHY327</td>
<td>History of Astronomy</td>
<td>10</td>
</tr>
<tr>
<td>PSY358</td>
<td>Current Controversies in the Psychology of Addition</td>
<td>10</td>
</tr>
</tbody>
</table>

For details of the Languages for All modules, see https://www.sheffield.ac.uk/languages/lfa/modules.

**BSc Mathematics with Spanish/French/German Language (MASU18/19/20), Year 4**

You must take modules to the value of **80 credits** from the Level 3 modules listed below:

<table>
<thead>
<tr>
<th>Code</th>
<th>Module</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS301</td>
<td>Group Project</td>
<td>10</td>
</tr>
<tr>
<td>MAS302</td>
<td>Undergraduate Ambassador Scheme in Mathematics</td>
<td>20</td>
</tr>
<tr>
<td>MAS31001</td>
<td>Generalised Linear Models</td>
<td>10</td>
</tr>
<tr>
<td>MAS322</td>
<td>Operations Research</td>
<td>10</td>
</tr>
<tr>
<td>MAS330</td>
<td>Topics in Number Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS331</td>
<td>Metric Spaces</td>
<td>10</td>
</tr>
<tr>
<td>MAS332</td>
<td>Complex Analysis</td>
<td>10</td>
</tr>
<tr>
<td>MAS333</td>
<td>Fields</td>
<td>10</td>
</tr>
<tr>
<td>MAS334</td>
<td>Combinatorics</td>
<td>10</td>
</tr>
<tr>
<td>MAS336</td>
<td>Differential Geometry</td>
<td>10</td>
</tr>
<tr>
<td>MAS341</td>
<td>Graph Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS343</td>
<td>History of Mathematics</td>
<td>10</td>
</tr>
<tr>
<td>MAS344</td>
<td>Knots and Surfaces</td>
<td>10</td>
</tr>
<tr>
<td>MAS345</td>
<td>Codes and Cryptography</td>
<td>10</td>
</tr>
<tr>
<td>MAS346</td>
<td>Groups and Symmetry</td>
<td>10</td>
</tr>
<tr>
<td>MAS348</td>
<td>Game Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS350</td>
<td>Measure and Probability</td>
<td>10</td>
</tr>
<tr>
<td>MAS360</td>
<td>Practical and Applied Statistics</td>
<td>20</td>
</tr>
<tr>
<td>MAS361</td>
<td>Medical Statistics</td>
<td>10</td>
</tr>
<tr>
<td>MAS362</td>
<td>Financial Mathematics</td>
<td>10</td>
</tr>
<tr>
<td>MAS364</td>
<td>Bayesian Statistics</td>
<td>10</td>
</tr>
<tr>
<td>MAS369</td>
<td>Machine Learning</td>
<td>10</td>
</tr>
<tr>
<td>MAS370</td>
<td>Sampling Theory and Design of Experiments</td>
<td>10</td>
</tr>
</tbody>
</table>
You must also take modules to the value of 40 credits in the appropriate foreign language.

**BSc Financial Mathematics (MASU05), Year 3**

You **must** take:

- **MAS331** Metric Spaces 10 credits
- **MAS352** Stochastic Processes and Finance 20 credits
- **MAS362** Financial Mathematics 10 credits

and modules to the value of 40 credits from the list:

- **MAS301** Group Project 10 credits
- **MAS31001** Generalised Linear Models 10 credits
- **MAS322** Operations Research 10 credits
- **MAS330** Topics in Number Theory 10 credits
- **MAS332** Complex Analysis 10 credits
- **MAS334** Combinatorics 10 credits
- **MAS336** Differential Geometry 10 credits
- **MAS341** Graph Theory 10 credits
- **MAS343** History of Mathematics 10 credits
- **MAS344** Knots and Surfaces 10 credits
- **MAS345** Codes and Cryptography 10 credits
- **MAS348** Game Theory 10 credits
- **MAS350** Measure and Probability 10 credits
- **MAS360** Practical and Applied Statistics 20 credits
- **MAS361** Medical Statistics 10 credits
- **MAS364** Bayesian Statistics 10 credits
- **MAS369** Machine Learning 10 credits
- **MAS370** Sampling Theory and Design of Experiments 10 credits
- **MAS371** Applied Probability 10 credits
- **MAS372** Time Series 10 credits

and modules to the value of 40 credits from either:

- **ECN357** Modern Finance 20 credits
- **MGT321** Corporate Finance 20 credits
- **MGT375** Financial Derivatives 20 credits

or from:
ECN301 Advanced Microeconomics 20 credits
ECN302 Advanced Macroeconomics 20 credits
ECN340 Further Econometrics 20 credits
ECN357 Modern Finance 20 credits

MMath Mathematics with Study in Europe (MASU10) or with A Year Abroad (MASU15), Year 3

You will spend Year 3 studying at an overseas university. However, you should try to ensure that in 2021–2022, at that overseas university, you acquire the prerequisites for the Level 4 courses you want to take in 2022–2023. See the warning on choice of modules on p.6. You are strongly advised to consult the member of staff with special responsibility for your programme (see http://maths.dept.shef.ac.uk/maths/contact.html for the current list) about this aspect.

BSc Mathematics with Study in Europe (MASU11), Year 3

You will spend Year 3 studying at an overseas university. You will undertake studies equivalent to 120 credits of work, with up to 20 credits from MLT units. On return to Sheffield, in 2022–2023, you will take Level 3 courses.

MMath Mathematics with Spanish/French/German Language (MASU12/13/14), Year 3

You will spend Year 3 studying at an overseas university. In your fourth year, back in Sheffield, you will be required to take 80 credits of SoMaS Level 4 modules, and the compulsory project modules provide 40 of these credits. Further details of these are given below. You should plan carefully so that in 2021–2022 at that overseas university, you acquire the prerequisites for the Level 4 modules you want to take in 2022–2023. See the warning on choice of modules on p.6. You are strongly advised to consult the programme leader for advice (see http://maths.dept.shef.ac.uk/maths/contact.html for the current list).

BSc Mathematics with Spanish/French/German Language (MASU18/19/20), Year 3

You will spend Year 3 studying at an overseas university. On return to Sheffield, in 2022–2023, you will take Level 3 courses.

MMath Mathematics (MASU02), Years 3 and 4

Across Years 3 and 4, you must take modules to the value of 120 credits from Level 4 modules listed on the following pages. It is expected that you would normally take 120 credits of Level 4 modules in Year 4; however, you may take up to 20 credits of Level 4 modules; you may then
take Level 3 modules in Year 4 as long as you take at least 120 credits of Level 4 modules in total.

In order to progress to Year 4, you should normally have been awarded 120 credits in Year 3 and have obtained a weighted mean grade in Year 3 of not less than 59.5.

You should plan carefully so that in 2021–2022 you acquire the prerequisites for the Level 4 courses you want to take in 2022–2023. See the warning on choice of modules on p.6.

In Year 3, you will take modules to the value of 120 credits from the following Level 3 modules:

- **MAS301** Group Project 10 credits
- **MAS302** Undergraduate Ambassador Scheme in Mathematics 20 credits
- **MAS310** Continuum Mechanics 10 credits
- **MAS31001** Generalised Linear Models 10 credits
- **MAS314** Introduction to Relativity 10 credits
- **MAS315** Waves 10 credits
- **MAS316** Mathematical Modelling of Natural Systems 10 credits
- **MAS320** Fluid Mechanics I 10 credits
- **MAS322** Operations Research 10 credits
- **MAS324** Quantum Theory 10 credits
- **MAS325** Mathematical Methods 10 credits
- **MAS330** Topics in Number Theory 10 credits
- **MAS331** Metric Spaces 10 credits
- **MAS332** Complex Analysis 10 credits
- **MAS333** Fields 10 credits
- **MAS334** Combinatorics 10 credits
- **MAS336** Differential Geometry 10 credits
- **MAS341** Graph Theory 10 credits
- **MAS343** History of Mathematics 10 credits
- **MAS344** Knots and Surfaces 10 credits
- **MAS345** Codes and Cryptography 10 credits
- **MAS346** Groups and Symmetry 10 credits
- **MAS348** Game Theory 10 credits
- **MAS350** Measure and Probability 10 credits
- **MAS352** Stochastic Processes and Finance 20 credits
- **MAS360** Practical and Applied Statistics 20 credits
- **MAS361** Medical Statistics 10 credits
- **MAS362** Financial Mathematics 10 credits
- **MAS364** Bayesian Statistics 10 credits
- **MAS369** Machine Learning 10 credits
- **MAS370** Sampling Theory and Design of Experiments 10 credits
- **MAS371** Applied Probability 10 credits
- **MAS372** Time Series 10 credits
- **MAS377** Mathematical Biology 10 credits

(a) You may replace up to 20 credits of the Level 3 modules by additional optional modules from the following list if you are not taking **MAS302** (Undergraduate Ambassador Scheme in Mathematics) (see the section on additional optional modules on p.6 for details of the conditions that apply).
<table>
<thead>
<tr>
<th>Module Code</th>
<th>Module Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>APS31006</td>
<td>Human Planet</td>
<td>10</td>
</tr>
<tr>
<td>APS341</td>
<td>Evolution of Terrestrial Ecosystems</td>
<td>10</td>
</tr>
<tr>
<td>APS344</td>
<td>Topics in Evolutionary Genetics</td>
<td>10</td>
</tr>
<tr>
<td>APS346</td>
<td>Sustainable Agro-Ecosystems</td>
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</tr>
<tr>
<td>COM3110</td>
<td>Text Processing</td>
<td>10</td>
</tr>
<tr>
<td>COM3240</td>
<td>Adaptive Intelligence</td>
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<tr>
<td>COM3502</td>
<td>Speech Processing</td>
<td>10</td>
</tr>
<tr>
<td>EDU309</td>
<td>Globalising Education</td>
<td>20</td>
</tr>
<tr>
<td>PHI372</td>
<td>Pain, Pleasure, and Emotions</td>
<td>20</td>
</tr>
<tr>
<td>PHY327</td>
<td>History of Astronomy</td>
<td>10</td>
</tr>
<tr>
<td>PSY358</td>
<td>Current Controversies in the Psychology of Addition</td>
<td>10</td>
</tr>
</tbody>
</table>

Languages for All modules

For details of the Languages for All modules, see [https://www.sheffield.ac.uk/languages/lfa/modules](https://www.sheffield.ac.uk/languages/lfa/modules).

(b) You may replace up to 20 credits of the Level 3 modules by Level 4 modules (excluding MAS400 and MAS406) if you are not taking MAS302.

In Year 4, your choice of Level 4 modules must include 40 credits of project modules:

- **MAS400**  Project Presentation in Mathematics and Statistics  10 credits
- **MAS406**  Mathematics and Statistics Project II  30 credits

Further details of these are given below. In addition, you will take either 80 credits from the following Level 4 modules:

<table>
<thead>
<tr>
<th>Module Code</th>
<th>Module Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS411</td>
<td>Topics in Advanced Fluid Mechanics</td>
<td>20</td>
</tr>
<tr>
<td>MAS413</td>
<td>Analytical Dynamics and Classical Field Theory</td>
<td>20</td>
</tr>
<tr>
<td>MAS414</td>
<td>Mathematical Modelling of Natural Systems (Advanced)</td>
<td>10</td>
</tr>
<tr>
<td>MAS420</td>
<td>Signal Processing</td>
<td>10</td>
</tr>
<tr>
<td>MAS422</td>
<td>Magnetohydrodynamics</td>
<td>10</td>
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<td>MAS423</td>
<td>Advanced Operations Research</td>
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<td>MAS430</td>
<td>Analytic Number Theory</td>
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<td>MAS435</td>
<td>Algebraic Topology</td>
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<td>MAS436</td>
<td>Functional Analysis</td>
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<tr>
<td>MAS438</td>
<td>Fields</td>
<td>10</td>
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<td>MAS439</td>
<td>Commutative Algebra and Algebraic Geometry</td>
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<td>MAS61002</td>
<td>Medical Statistics</td>
<td>15</td>
</tr>
<tr>
<td>MAS61003</td>
<td>Sampling Theory and Design of Experiments</td>
<td>15</td>
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<tr>
<td>MAS61005</td>
<td>Time Series</td>
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<tr>
<td>MAS61006</td>
<td>Bayesian Statistics and Computational Methods</td>
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<tr>
<td>MAS61007</td>
<td>Machine Learning</td>
<td>15</td>
</tr>
<tr>
<td>PHY421</td>
<td>Advanced Particle Physics</td>
<td>10</td>
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</tbody>
</table>
PHY472 Advanced Quantum Mechanics 10 credits

or 80 credits from both Level 3 and Level 4 modules, with no more than 20 credits from the Level 3 modules.

MMath Mathematics and Statistics (MASU39) Year 4

If you are interested in switching to this degree please talk to the Senior Tutor about it. In particular you need to be sure that you have taken the correct modules at previous Levels.

In addition to the 40 credits of project modules MAS400 and MAS406 (for which the topic must be in statistics or probability) you must take:

- **MAS61001** Generalised Linear Models 15 credits
- **MAS61006** Bayesian Statistics and Computational Methods 30 credits
- **MAS61007** Machine Learning 15 credits

and modules to the value of 20 credits from the following modules:

- **MAS310** Continuum Mechanics 10 credits
- **MAS314** Introduction to Relativity 10 credits
- **MAS315** Waves 10 credits
- **MAS316** Mathematical Modelling of Natural Systems 10 credits
- **MAS320** Fluid Mechanics I 10 credits
- **MAS322** Operations Research 10 credits
- **MAS324** Quantum Theory 10 credits
- **MAS325** Mathematical Methods 10 credits
- **MAS330** Topics in Number Theory 10 credits
- **MAS331** Metric Spaces 10 credits
- **MAS332** Complex Analysis 10 credits
- **MAS333** Fields 10 credits
- **MAS334** Combinatorics 10 credits
- **MAS336** Differential Geometry 10 credits
- **MAS341** Graph Theory 10 credits
- **MAS343** History of Mathematics 10 credits
- **MAS344** Knots and Surfaces 10 credits
- **MAS345** Codes and Cryptography 10 credits
- **MAS346** Groups and Symmetry 10 credits
- **MAS348** Game Theory 10 credits
- **MAS362** Financial Mathematics 10 credits
- **MAS372** Time Series 10 credits
- **MAS377** Mathematical Biology 10 credits
- **MAS411** Topics in Advanced Fluid Mechanics 20 credits
- **MAS413** Analytical Dynamics and Classical Field Theory 20 credits
- **MAS414** Mathematical Modelling of Natural Systems (Advanced) 10 credits
- **MAS420** Signal Processing 10 credits
- **MAS422** Magnetohydrodynamics 10 credits
- **MAS423** Advanced Operations Research 10 credits
### MMath Mathematics with Study in Europe (MASU10) Year 4, MMath Mathematics with Year Abroad (MASU15) Year 4

In Year 4, you need to take 120 credits of Level 4 modules (for this purpose, language courses offered to students on the MMath Mathematics with Study in Europe degree may count as Level 4, even though their code is MLT3**).

Your choice of Level 4 modules must include 40 credits of project modules. These consist of MAS400 and MAS406. Further details of these are given below.

The remaining 80 credits must be taken from the list below except that students taking the MMath Mathematics with Study in Europe degree in their fourth year may replace up to 20 credits with language modules at the appropriate level.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>MAS411</td>
<td>Topics in Advanced Fluid Mechanics</td>
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<tr>
<td>MAS413</td>
<td>Analytical Dynamics and Classical Field Theory</td>
<td>20</td>
</tr>
<tr>
<td>MAS414</td>
<td>Mathematical Modelling of Natural Systems (Advanced)</td>
<td>10</td>
</tr>
<tr>
<td>MAS420</td>
<td>Signal Processing</td>
<td>10</td>
</tr>
<tr>
<td>MAS422</td>
<td>Magnetohydrodynamics</td>
<td>10</td>
</tr>
<tr>
<td>MAS423</td>
<td>Advanced Operations Research</td>
<td>10</td>
</tr>
<tr>
<td>MAS430</td>
<td>Analytic Number Theory</td>
<td>10</td>
</tr>
<tr>
<td>MAS435</td>
<td>Algebraic Topology</td>
<td>20</td>
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<tr>
<td>MAS436</td>
<td>Functional Analysis</td>
<td>20</td>
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<tr>
<td>MAS438</td>
<td>Fields</td>
<td>10</td>
</tr>
<tr>
<td>MAS439</td>
<td>Commutative Algebra and Algebraic Geometry</td>
<td>20</td>
</tr>
<tr>
<td>MAS442</td>
<td>Galois Theory</td>
<td>10</td>
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<tr>
<td>MAS451</td>
<td>Measure and Probability</td>
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<tr>
<td>MAS452</td>
<td>Stochastic Processes and Finance</td>
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<tr>
<td>MAS462</td>
<td>Financial Mathematics</td>
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<tr>
<td>PHY421</td>
<td>Advanced Particle Physics</td>
<td>10</td>
</tr>
<tr>
<td>PHY472</td>
<td>Advanced Quantum Mechanics</td>
<td>10</td>
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</tbody>
</table>
MMath Mathematics with Spanish/French/German Language (MASU12/13/14) Year 4

In your fourth year, you must take modules to the value of 40 credits in the appropriate foreign language and modules to the value of 80 credits from the Level 4 mathematics modules. You do not have the option of taking an unrestricted module in your fourth year.

Your choice of Level 4 modules must include 40 credits of project modules. These consist of MAS400 and MAS406. Further details of these are given below.

The remaining 40 credits must be taken from:

- **MAS420** Signal Processing 10 credits
- **MAS423** Advanced Operations Research 10 credits
- **MAS430** Analytic Number Theory 10 credits
- **MAS435** Algebraic Topology 20 credits
- **MAS436** Functional Analysis 20 credits
- **MAS438** Fields 10 credits
- **MAS439** Commutative Algebra and Algebraic Geometry 20 credits
- **MAS462** Financial Mathematics 10 credits
- **MAS442** Galois Theory 10 credits
- **MAS451** Measure and Probability 10 credits
- **MAS452** Stochastic Processes and Finance 20 credits
- **MAS462** Financial Mathematics 10 credits
- **MAS61001** Generalised Linear Models 15 credits
- **MAS61002** Medical Statistics 15 credits
- **MAS61003** Sampling Theory and Design of Experiments 15 credits
- **MAS61005** Time series 15 credits
- **MAS61006** Bayesian Statistics and Computational Methods 30 credits
- **MAS61007** Machine Learning 15 credits

BSc Mathematics with Placement Year (MASU40), MMath Mathematics with Placement Year (MASU41), BSc Mathematics and Statistics with Placement Year (MASU42), MMath Mathematics and Statistics with Placement Year (MASU43)

These are the Placement Year (see p.8) equivalents of MASU01, MASU02, MASU38 and MASU39 respectively.
Assessment of Year Overseas

On certain degrees a student will spend a year at Level 3 studying in an overseas university, registered for certain of the modules offered by that institution. That institution will produce marks for the student for those modules, within their system, and we will receive a transcript containing those marks, which we then have to convert to a mark according to the Sheffield grading convention. This mark will be what counts towards their degree (but for the BSc degrees it is simply pass/fail). This conversion is done by a SoMaS committee. They work on a case by case basis, taking into account various factors including some or all of the following:

- any known approximate correspondence of classifications between the UK system and the system of the country in question;
- past experience of the particular university and its grading system;
- review of the syllabuses of the modules and how their level and content compares with our own;
- any relevant factors identified in the portfolio produced by the student, which should be a detailed record of their coursework (essay papers, exams, projects, solutions to problem sheets, module syllabi).

Unconfirmed marks for the Study Abroad module will be released to students during Semester 1 of their 4th year, so that they have some idea where they stand, but they will be subject to confirmation by Faculty at the usual time following the February exam board meeting.
The Level 4 Project

The Level 4 project is available only to MMath Mathematics, MMath Mathematics and Statistics, MMath Mathematics with Study in Europe, MMath Mathematics with Year Abroad, and MMath Mathematics with Spanish, French or German Language students, in their fourth year, and to students on MMath Mathematics with Placement Year or MMath Mathematics and Statistics with Placement Year.

The project has two parts.

(a) **MAS400 Project Presentation in Mathematics and Statistics** *(Autumn Semester, 10 credits)*

This 10-credit module provides further training and experience in the use of appropriate computer packages (in particular LaTeX) for the presentation of mathematics and statistics, and guidance on the coherent and accurate presentation of technical information.

**Aims:**

1. to develop written and oral communication skills,
2. to develop general presentational skills usable in a wider context,
3. to train students in the use of appropriate software for the presentation of mathematics and statistics.

The spine of the module is a sequence of six laboratory sessions which are designed to provide further training in LaTeX and mathematical writing. These are supplemented by three lectures on written and oral presentation and three group discussions, with a focus on peer review, which support the assessment process.

Your assessment will be based on several pieces of written work relevant to your project area and on a fifteen-minute oral presentation. These will be assessed using a marking scheme explicitly addressing the expected learning outcomes:

1. skill in the use of appropriate computer software in presenting mathematics,
2. ability to present an argument precisely and coherently, and
3. ability to communicate ideas effectively.

(b) **MAS406 Mathematics and Statistics Project** *(all year, 30 credits)*

This is the main module in the School’s project provision at Level 4 and introduces you to the experience of researching and presenting an advanced topic in your chosen subject area under the guidance of a research-active supervisor.

**Aims:** to give students experience of, and training in, research and presentation of an advanced mathematical topic. In particular:

1. to support the development of independent study skills,
2. to support the acquisition of communication and presentation skills,
3. to provide an opportunity for the student to experience research,
4. to give the opportunity to study a specialist topic of attraction to the student.
You will choose a topic from a list made available in advance of the session. You will then have meetings with your supervisor, following a recommended schedule, at which you will be given guidance on appropriate resources, such as library and internet, and feedback on your progress. Training in the use of appropriate software for presentation is provided in the corequisite module MAS400 and more specialist advice and feedback, pertaining to the individual project topic, will be given by your supervisor.

In the autumn semester, the students will begin to understand the topic of the project, and will write a draft report of part of the project for feedback purposes.

This report is expected to be a preliminary report on a substantial project, to be continued in the spring semester. However, in exceptional circumstances, the student might be permitted to switch to a different topic in the spring semester.

The final report at the end of the spring semester is expected to be more substantial, at around 30–40 pages.

The module will be assessed on the basis of the report, and reference to expected learning outcomes:

1. specialist knowledge of an advanced mathematical topic,
2. ability to research an advanced mathematical topic,
3. ability to present an accurate and coherent report on a mathematical topic,
4. general presentational skills including correct usage of language and grammar,
5. ability to use library and internet resources effectively,
6. skill in using appropriate software for the presentation of mathematics, the most substantial component being for mathematical accuracy.

Assessment of reports will be by two members of staff and will be subject to moderation by a project coordinator. Both your report and a report by the assessors will be made available to the External Examiner. The student will give a presentation on the spring semester material, and this will contribute to the assessment of MAS406.

With permission of the Director of Teaching, the 30-credit module MAS406 may be replaced by MAS407, a 40-credit module, with a larger spring semester component. Permission to take this larger project module is likely to be granted only in exceptional circumstances.

Other Level 3/4 modules

Most of the remainder of this document contains descriptions of the other modules offered by SoMaS at Levels 3 and 4; the final section gives a grid summarising the provisional schedule.
7 Cover sheet arrangements

There are some special arrangements for when assessed coursework is to be handed in at SoMaS Reception (F10).

(i) All work that needs to be submitted to Reception (F10) needs to have a cover sheet.
(ii) Students can access the cover sheet via https://sciencecoversheet.group.shef.ac.uk/:

(a) log in with your university user name and password;
(b) cover sheets become available to students one week before the deadline to avoid early submissions;
(c) cover sheets are unique to each student – printing out a coversheet for a friend doesn’t work!

(iii) This then needs to be stapled (or in a plastic wallet) and then posted into the drop box outside reception (the drop box is provided for work that is either late/early or being submitted out of office opening times).

If students have any problems with regards to viewing/accessing the cover sheets, contact hicksstudentsupport@sheffield.ac.uk or visit Reception (F10) to try and sort out the problem.
8 Planned schedule of courses

This section contains a list of the modules we currently intend to offer next year (and, in the case of Level 4 courses, in 2022–2023). This list should be regarded as provisional. The semesters when the courses are NOT available are blacked out.

<table>
<thead>
<tr>
<th>Levels 3 and 4: Year-Long Modules in 2021–2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAS302 Undergraduate Ambassador Scheme in Mathematics (20 credits)</td>
</tr>
<tr>
<td>MAS352 Stochastic Processes and Finance (20 credits)</td>
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<tr>
<td>MAS360 Practical and Applied Statistics (20 credits)</td>
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<td>MAS406 Mathematics and Statistics Project (30 credits)</td>
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<td>MAS413 Analytical Dynamics and Classical Field Theory (20 credits)</td>
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<td>MAS435 Algebraic Topology (20 credits)</td>
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<td>MAS436 Functional Analysis (20 credits)</td>
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<td>MAS439 Commutative Algebra and Algebraic Geometry (20 credits)</td>
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<td>MAS452 Stochastic Processes and Finance (20 credits)</td>
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<td>MAS61002 Medical Statistics (15 credits)</td>
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<tr>
<td>MAS61006 Bayesian Statistics and Computational Methods (30 credits)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 3</th>
<th>Semester Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module</td>
<td>Autumn 2021</td>
</tr>
<tr>
<td>MAS301 Group Project</td>
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<tr>
<td>MAS310 Continuum Mechanics</td>
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</tr>
<tr>
<td>MAS31001 Generalised Linear Models</td>
<td>☐</td>
</tr>
<tr>
<td>MAS314 Introduction to Relativity</td>
<td>☐</td>
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<tr>
<td>MAS315 Waves</td>
<td>☐</td>
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<tr>
<td>MAS316 Mathematical Modelling of Natural Systems</td>
<td>☐</td>
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<tr>
<td>MAS320 Fluid Mechanics I</td>
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<tr>
<td>MAS322 Operations Research</td>
<td>☐</td>
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<tr>
<td>MAS324 Quantum Theory</td>
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<tr>
<td>MAS325 Mathematical Methods</td>
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<td>MAS330 Topics in Number Theory</td>
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<td>MAS331 Metric Spaces</td>
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<td>MAS336 Differential Geometry</td>
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<td>MAS341 Graph Theory</td>
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<td>MAS343 History of Mathematics</td>
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<td>MAS344 Knots and Surfaces</td>
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<tr>
<td>MAS345 Codes and Cryptography</td>
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</table>
MAS346 Groups and Symmetry
MAS348 Game Theory
MAS350 Measure and Probability
MAS361 Medical Statistics
MAS362 Financial Mathematics
MAS364 Bayesian Statistics
MAS369 Machine Learning
MAS370 Sampling Theory & Design of Experiments
MAS371 Applied Probability
MAS372 Time Series
MAS377 Mathematical Biology

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<tr>
<th>Module</th>
<th>Autumn 2021</th>
<th>Spring 2022</th>
<th>Autumn 2022</th>
<th>Spring 2023</th>
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<tbody>
<tr>
<td>MAS400 Project Presentation in Maths. &amp; Stats.</td>
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<tr>
<td>MAS411 Advanced Fluid Mechanics (20 credits)</td>
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<td>MAS414 Math. Modelling of Natural Systems</td>
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<td>MAS420 Signal Processing</td>
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<td>MAS422 Magnetohydrodynamics</td>
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<td>MAS423 Advanced Operations Research</td>
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<td>MAS438 Fields</td>
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<td>MAS442 Galois Theory</td>
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<td>MAS451 Measure and Probability</td>
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<td>MAS462 Financial Mathematics</td>
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<td>MAS61001 Generalised Linear Models</td>
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<td>MAS61003 Sampling Theory and Design of Experiments</td>
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<td>MAS61007 Machine Learning</td>
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<tr>
<td>PHY421 Advanced Particle Physics</td>
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<tr>
<td>PHY472 Advanced Quantum Mechanics</td>
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</table>

Timetabling of Classes

At the time of writing, the timetable for the academic year 2021–2022 was not available. Information about the timetabling of classes will be put on the SoMaS webpage as soon as it is available (likely to be in September 2021). Please note that sometimes various Level 3 and Level 4 modules have classes at the same time. You will not be able to take more than one module which has the same lecture times. While we strive to keep clashes to a minimum, it
may be necessary to change your module choices in September 2021 after the timetable has been finalised.
MAS301: Group Project
Semester: 1 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with: MAS360 (Practical and Applied Statistics);
MAS400 (Project Presentation in Mathematics and Statistics)
Prerequisite for:

Description
This module will provide students with opportunities to improve their transferable skills by working in groups of (normally) four students to investigate a mathematical project topic. It is suggested that students register for MAS301 in pre-formed groups, although this is not obligatory. With the aid of the library and the internet each group will produce a (single) written account of the group’s investigations into the topic, and contribute to an oral presentation of their work. Topics will be proposed by members of staff, but groups may propose their own. The module coordinator will provide guidance about working in groups, and on appropriate techniques for the written and oral presentation of mathematical topics.

Aims
- To provide opportunities for students to improve their transferable skills
- To provide an opportunity for students to gain experience of working in small groups
- To provide an opportunity for students to develop their information retrieval skills
- To provide an opportunity for students to improve their ability to construct a joint, written report that demonstrates their understanding of an advanced mathematical topic
- To provide an opportunity for students to enhance their skills in the preparation and delivery of oral presentations

Outline syllabus
There is no recorded outline syllabus for this module.

Module Format

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Tutorials</th>
<th>Practicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tbody>
</table>

Recommended books
- There are no recommended books for this course.

Assessment
Written group project dissertation (6,000 - 7,500 words) [65%].
25-minute oral group presentation [25%].
Individual’s contribution to work of group [10%].
MAS302: Undergraduate Ambassadors Scheme
Semester: Year 20 credits

Prerequisites: Agreement of module co-ordinator
Corequisites: Cannot be taken with: COM3550 (Undergraduate Ambassadors Scheme in Computer Science)
Prerequisite for: 

Description

MAS302 is a course which involves no formal lectures but which, instead, places students in the classroom environment of the Mathematics Departments of local secondary schools. The time spent within the allocated school is highly structured to ensure the desired outcomes of the course - see “Learning outcomes” and “Syllabus” section in the description for this module on SoMaS website.
Note that although the classroom activities take place in Semester 2, there is a selection process and some training which is held in Semester 1. Further, the presentation part of the assessment will be held in Semester 1. Students taking MAS302 might want to consider taking 70 credits in Semester 1 and 50 in Semester 2 as the course is time-intensive in Semester 2.

Aims

- To develop students’ confidence in their ability to act independently in the execution of complex and important tasks;
- To develop the complex skills required to communicate difficult subjects in a variety of ways to people of widely varying abilities;
- To develop the personal skills required to engage the attention of people as individuals and of people in groups;
- To learn the specific skills required to develop projects and teaching methods appropriate to the age group of pupils under tuition;
- To inspire a new generation of prospective undergraduates by providing positive role models in the classroom;
- To stimulate pupils by conveying the excitement of their subject and showing the long-term benefits of studying;
- To provide additional classroom support for teachers in the form of an assistant who can work with pupils at any point on the ability spectrum;
- To provide a short, but direct, experience of teaching to those interested in pursuing it as a career.

Outline syllabus

A competitive interview system will be used to select students for the module, and to match each successful applicant with an appropriate school and a specific teacher in the local area. An initial day of training - held before Christmas - will provide the students with an introduction to working and conduct in the school environment. Each student selected will be required to visit the school they will be working in before commencement of the unit - this visit will usually take place before Christmas. The students will be required to spend half a day (approximately 4 hours) each week in the school for ten weeks of the second semester. It is intended that there will be no formal lectures associated with the unit, and that wherever appropriate the students’ own ideas will increasingly define the nature of their teaching activities as they become more experienced. However, there will be supporting tutorials which will provide an opportunity for students to share their experiences with their contemporaries and the module coordinators. The teachers will act as the main source of guidance but, in addition, students will be able to discuss their progress with the module coordinators whenever necessary.

Assessment

A weekly diary [10%]; End-of-module written report [35%]; A written account of your special project [20%]; A fifteen minute oral presentation [20%] (held in Semester 1); Overall impression of the portfolio [8%]; Assessment by the teacher moderated by module coordinator [7%];
MAS310: Continuum Mechanics
Semester: 1 10 credits

Prerequisites: MAS280 (Mechanics and Fluids)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
Continuum mechanics is concerned with the mechanical behaviour of solids and fluids which change their shape when forces are applied. For example, rubber extends when pulled but behaves elastically returning to its original shape when the forces are removed. Water starts to move when external pressure is applied. This module aims to introduce the basic kinematic and mechanical ideas needed to model deformable materials and fluids mathematically. They are needed to develop theories which describe elastic solids and fluids like water. In this course, a theory for solids which behave elastically under small deformations is developed. This theory is also used in seismology to discuss wave propagation in the Earth. An introduction in theory of ideal and viscous, incompressible and compressible fluids is given. The theory is used to solve simple problems. In particular, the propagation of sound waves in the air is studied.

Aims

- To introduce the basic kinematic and mechanical ideas needed to model deformable solids and fluids.
- To introduce and illustrate the theory of classical elasticity with simple example of exact solutions and applications to seismology.
- To introduce the theory of ideal and viscous, incompressible and compressible fluids, and apply it to solve simple problems.

Outline syllabus

- Dynamics of continuum: Stress tensor and its main properties. Momentum equation. Boundary conditions at rigid and free surfaces.

Module Format

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Tutorials</th>
<th>Practicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
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</table>

Recommended books

B Atkin and Fox “An Introduction to the Theory of Elasticity” (Shelfmark 531.38 (A), ISBN 0486442411)
B Hunter “Mechanics of Continuous Media” (Shelfmark 531.01 (H), ISBN 0853125708)
B Spencer “Continuum Mechanics” (Shelfmark 531.01 (S), ISBN 0486435946)
B Thompson “An Introduction to Astrophysical Fluid Dynamics” (Shelfmark 523.01 (T), ISBN 186094633X)

Assessment
One formal 2 hour written examination. Format: 4 questions from 5.
MAS31001: Generalised Linear Models
Semester 2 10 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
This module introduces the theory and application of generalised linear models. Such models can be used for modelling binary or count data, where the dependent variable is not normally distributed; this increases substantially the range of problems that can be studied. The general theory will be presented, in which the ordinary linear model is a special case. Mixed effects models will also be discussed. Application of the methods will be demonstrated using R, including the use of exploratory data analysis methods as a precursor to modelling.

Aims
- To introduce the theory of generalised linear models, including the use of random effects.
- To show how these models are applied to data, and what kinds of conclusions are possible.
- To demonstrate how generalised linear models can be fitted to data using R.

Outline syllabus
- Introducing generalised linear models: theoretical concepts.
- Binomial, ordinal, multinomial and Poisson regression.
- Incorporating mixed effects in linear and generalised linear models.
- Implementation with R.

Module Format

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Recommended books
- B Faraway “Extending the linear model with R: Generalized linear, Mixed Effects and Nonparametric Regression models (Second edition)”

Assessment
One formal 2 hour examination [100%].
MAS314: Introduction to Relativity
Semester: 1 10 credits

Prerequisites:  
Corequisites:  
Cannot be taken with:  
Prerequisite for:  

Description

Einstein’s theory of relativity is one of the cornerstones of our understanding of the universe. This course will introduce some of the ideas of relativity and the physical consequences of the theory, many of which are highly counter-intuitive. For example, a rapidly moving body will appear to be contracted as seen by an observer at rest. The course will also introduce one of the most famous equations in the whole of mathematics: \( E = Mc^2 \).

Aims

- To motivate the need for relativity as a theory;
- To introduce the key ideas;
- To introduce some simple applications in collisions and kinematics.

Outline syllabus

- **The need for special relativity:** Galilean relativity in Newtonian Mechanics. “Ether”, or lack of it.
- **Foundations of special relativity:** Postulates of special relativity; Lorentz transformations; time dilation; length contraction, Minkowski space.
- **Kinematics in special relativity:** Velocity and acceleration four-vectors; uniform acceleration; momentum; \( E = Mc^2 \);
- **Collisions in special relativity:** Conservation of mass and momentum; applications to simple particle collisions.
- **The need for general relativity:** Why special relativity cannot be the whole story.

Module Format

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Recommended books

- B d’Inverno “Introducing Einstein’s Relativity” (Shelfmark 530.11 (D), ISBN 0198596863)
- B Giulini “Special Relativity - A First Encounter: 100 Years Since Einstein” (Shelfmark 530.11 (G), ISBN 0198567464)
- B Rindler “Introduction to Special Relativity” (Shelfmark 530.11 (R), ISBN 0198539525)
- C Feynman “Six not-so-easy pieces: Einstein’s Relativity, Symmetry, and Space-time” (Shelfmark 530 (F))

Assessment

One formal 2 hour written examination.
MAS315: Waves
Semester: 1 10 credits

Prerequisites: MAS112 (Vectors and Mechanics)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
Studying wave phenomena has had a great impact on Applied Mathematics. This module looks at some important wave motions with a view to understanding them by developing from first principles the key mathematical tools. We begin with waves on strings (e.g. a piano or violin), developing the concept of standing and progressive waves, and normal modes. Fourier series are used to solve problems relating to waves on strings and membranes. Sound waves and water waves are considered. The concepts of dispersion and group velocity are introduced. The course concludes with consideration of “traffic waves” as the simplest example of nonlinear waves.

Aims
- To introduce wave propagation.
- To derive important mathematical tools to deal with problems of wave theory.
- To consider simple examples of linear waves on strings, sound waves and water waves.
- To give you one of simplest examples of nonlinear waves.

Outline syllabus
- Use of Fourier series for solving one-dimensional wave problems.
- Sound waves. Plane, cylindrical and spherical sound waves.
- Traffic waves.

Module Format
Lectures 20  Tutorials 0  Practicals 0

Recommended books
B Knobel “An Introduction to the Mathematical Theory of Waves” (Shelfmark 531.1133 (K), ISBN 0821820397)
B Billingham and King “Wave Motion” (Shelfmark 531.33 (B), ISBN 0521634504)
B Whitham “Linear and Nonlinear Waves” (Shelfmark 531.33 (W), ISBN 047135942)
B Lighthill “Waves in Fluids” (Shelfmark 532.0593 (L), ISBN 052101045)

Assessment
One formal 2 hour written examination. Format: 4 questions from 5.
MAS316: Mathematical Modelling of Natural Systems
Semester: 2 10 credits

Prerequisites: MAS212 (Scientific Computing and Simulation); Please contact the lecturers if you wish to take this course but have not taken MAS212; MAS222 (Differential Equations)

Corequisites: Cannot be taken with: MAS414 (Mathematical Modelling of Natural Systems)
Prerequisite for:

Description
Mathematical modelling enables insight into a wide range of scientific problems. This module will provide a practical introduction to techniques for modelling natural systems. Students will learn how to construct, analyse and interpret mathematical models, using a combination of differential equations, scientific computing and mathematical reasoning. Students will learn the art of mathematical modelling: translating a scientific problem into a mathematical model, identifying and using appropriate mathematical tools to analyse the model, and finally relating the significance of the mathematical results back to the original problem. Study systems will be drawn from throughout the environmental and life sciences.

Aims

• develop students’ skills in comprehending problems, formulating them mathematically and obtaining solutions by appropriate methods;
• provide practical demonstrations of how mathematical modelling may be used to gain insight into the dynamics of natural systems;
• build on mathematical methods (ordinary/partial differential equations, linear stability analysis, scientific computing in Python) learned at earlier levels, and expose students to how they can be used to model natural systems.

Outline syllabus
You will study three specific topics related to modelling natural systems, which could include

• An introduction to chaotic dynamics.
• Spatial pattern formation in biology.
• Machine learning methods to retrieve forest biophysical parameters.

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Recommended books

B Hastie, Tibshirani, Friedman “The Elements of Statistical Learning: Data Mining, linference, and Prediction” (Shelfmark 006.31(H))
B Murray “Mathematical Biology” (Shelfmark 570.15118 (M), ISBN 9780387952239)
B Strogatz “Nonlinear Dynamics and Chaos” (Shelfmark 531.3(S), ISBN 9780738204536)

Assessment
3 pieces of coursework, with no examination.
**MAS320: Fluid Mechanics I**
Semester: 2 10 credits

Prerequisites: MAS222 (Differential Equations); MAS280 (Mechanics and Fluids)
Corequisites:
Cannot be taken with:
Prerequisite for:

**Description**
The way in which fluids move is of immense practical importance; the most obvious examples of this are air and water, but there are many others such as lubricants in engines. Moreover, the scientific principles and mathematical techniques needed to explain fluid motion are of intrinsic interest. This module builds on Level 2 work (MAS222 Differential Equations; MAS280 Mechanics and Fluids).
The first step is to derive the equation (Navier-Stokes) governing the motions of most common fluids. This serves as a basis for the remainder of MAS320, with the main addition to MAS280 being that it covers viscous (frictional) fluids.

**Aims**
- To broaden the students' knowledge of Fluid Mechanics, in particular by introducing them to viscous fluids.
- To introduce students to the mathematical and physical concepts used in the area of Fluid Dynamics.

**Outline syllabus**
- Rate of strain tensor, constitutive equation, Navier-Stokes equation.
- The stress vector.
- Exact solutions of the Navier-Stokes equation: simple shear flow, Poiseuille flow, steady flow under gravity down an inclined plane, flow between rotating cylinders, infinite plate impulsively started into motion.
- Reynolds number and the vorticity equation. The Burgers vortex.
- Small Reynolds number flow, the flow past a sphere, flow through a tube with slowly varying radius.
- Boundary layer theory: flow past a flat plate, skin friction, displacement thickness, momentum thickness, the Blasius solution, the Kármán-Pohlhausen approximation method.

**Module Format**

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**Recommended books**
- A Acheson “Elementary Fluid Dynamics” (Shelfmark 532.5 (A), ISBN 0198596790)
- B Landau and Lifshitz “Fluid Mechanics” (Shelfmark 530.1 (L), ISBN 0750627670)
- B Paterson “A First Course in Fluid Dynamics” (Shelfmark 532.51 (P), ISBN 0521274249)
- B Rosenhead “Laminar Boundary Layers” (Shelfmark 629.13237 (R), ISBN 0486656462)

**Assessment**
One formal two-hour written examination. Format: 4 compulsory questions.
MAS322: Operations Research
Semester: 2 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Coresquisites:
Cannot be taken with: MAS423 (Advanced Operations Research)
Prerequisite for:

Description
Mathematical Programming is the title given to a collection of optimisation algorithms that deal with constrained optimisation problems. In this module the problems considered will mostly involve constraints which are linear, and for which the objective function to be maximised or minimised is also linear. Some of these problems are not continuously differentiable; special algorithms have to be developed. The module considers first how these problems arise from practical applications, then introduces the methods to find and analyse the solutions, and concludes with a brief introduction of the dual problems.

Aims
- To develop the mathematical skills that will provide you with the appropriate foundations for further mathematical studies.
- To enable you to analyse OR problems that may arise in your future employment.

Outline syllabus
- Building linear programming, integer programming and piecewise linear programming models
- Graphical techniques
- The Simplex Method and variants
- Matrix representation of the simplex algorithm
- Elementary post-optimality analysis
- Duality

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Recommended books

B Paul R. Thie and Gerard E. Keough “An Introduction to Linear Programming and Game Theory” (Shelfmark 518.7 (T), ISBN 978-047032866)
B Taha “Operations Research” (Shelfmark 519.38 (T), ISBN 0131889230)
C Bertsimas and Tsitsiklis “Introduction to Linear Optimization.” (Shelfmark 519.72 (B), ISBN 1886529191)
C Winston “Introduction to Mathematical Programming” (Shelfmark 519.7 (W), ISBN 0534359647)

Assessment
One formal 2 hour written examination with 4 compulsory questions [75%]. Mini-project [25%].
MAS324: Quantum Theory
Semester: 2 10 credits

Prerequisites: MAS112 (Vectors and Mechanics)
Corequisites: PHY202 (Quantum Mechanics)

Description
The development of quantum theory revolutionized both physics and mathematics during the 20th century. The theory has applications in many technological advances, including lasers, super-conductors, modern medical imaging techniques, transistors and quantum computers. This course introduces the basics of the theory and brings together many aspects of mathematics: for example, probability, matrices and complex numbers. Only first year mechanics is assumed, and other mathematical concepts will be introduced as they are needed.

Aims
- To introduce the subject of quantum mechanics;
- To study simple quantum systems;
- To introduce some of the historical aspects of the subject.

Outline syllabus
- **Historical introduction**: Brief introduction to the experiments leading to the development of quantum theory and motivation of Schrodinger’s equation.
- **Simple quantum systems**: Particle in an infinite potential well, stationary states, expectation values, conservation of probability; simple scattering, potential step, potential barrier, finite potential well; 2-D potential well, degeneracy; finite-dimensional quantum systems.
- **Mathematical aspects of quantum theory**: Position and momentum operators; commutation relations; uncertainty principle; quantum simple harmonic oscillators.

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Recommended books
- Bransden and Joachain “Introduction to Quantum Mechanics” (Shelfmark 530.12 (B), ISBN 0582444985)
- Davies “Quantum Mechanics” (Shelfmark 530.12 (D), ISBN 0710099622)
- Rae “Quantum Mechanics” (Shelfmark 530.12 (R), ISBN 0750308397)

Assessment
One formal 2 hour written examination.
MAS325: Mathematical Methods
Semester: 2 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites: Cannot be taken with:
Prerequisite for:

Description
This course introduces methods which are useful in many areas of mathematics. The emphasis will mainly be on obtaining approximate solutions to problems which involve a small parameter and cannot easily be solved exactly. These problems will include the evaluation of integrals. Examples of possible applications are: oscillating motions with small nonlinear damping, the effect of other planets on the Earth’s orbit around the Sun, boundary layers in fluid flows, electrical capacitance of long thin bodies, central limit theorem correction terms for finite sample size.

Aims
- To develop methods for solving differential equations using integral transforms and representations.
- To introduce asymptotic methods for solving algebraic equations.
- To introduce asymptotic methods for evaluating integrals.

Outline syllabus
- Integral methods and differential equations: Dirac δ-function, Fourier and Laplace transforms, applications to differential equations, Green functions.
- Asymptotic expansions: algebraic equations with small parameter, asymptotic expansion of functions defined by integrals.

Module Format

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Recommended books

C Barndorff-Nielsen and Cox “Asymptotic Techniques for Use in Statistics” (Shelfmark 519.5 (B), ISBN 0412314002)
C Bender and Orszag “Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory” (Shelfmark 515.350245 (B), ISBN 0387989315)
C Copson “Asymptotic Expansions” (Shelfmark 3 PER 510.5/CAM, ISBN 0521604826)
C Hinch “Perturbation Methods” (Shelfmark 517.9 (H), ISBN 0521373107)
C Jordan and Smith “Mathematical Techniques” (Shelfmark 510 (J), ISBN 0199249725)
C Kevorkian and Cole “Multiple Scale and Singular Perturbation Methods” (Shelfmark 517.9 (K), ISBN 0387942025)
C King, Billingham and Otto “Differential Equations” (Shelfmark 515.35 (K), ISBN 0521816580)
C Lin and Segel “Mathematics Applied to Deterministic Problems in the Natural Sciences” (Shelfmark 510 (L), ISBN 0898712297)
C Olver “Asymptotics and Special Functions” (Shelfmark 517.5217 (O), ISBN 1568810695)
C Van Dyke “Perturbation Methods in Fluid Mechanics” (Shelfmark 532 (V), ISBN 0915760010)

Assessment
One formal 2 hour written examination. Format: 4 questions from 5.
MAS330: Topics in Number Theory
Semester: 1 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with:
Prerequisite for: Recommended for MAS345 (Codes and Cryptography)

Description
The course covers topics in elementary Number Theory. This includes Modular Arithmetic, and properties of primes and integers. Most of the material (with the notable exception of the RSA cryptosystem) has been introduced by Fermat, Euler and Gauss in the 17th, 18th and 19th centuries.

Aims
- To introduce various topics in number theory

Outline syllabus
1. Modular Arithmetic
   - Linear Congruences
   - Fermat's Little Theorem and the RSA cryptosystem.
   - Arithmetic functions.
   - Euler's function and Euler's theorem.
   - Gauss' Quadratic Reciprocity Law.

2. Primes, Integers and Equations
   - Perfect numbers, Mersenne primes, Fermat primes.
   - Pythagorean triples and Fermat Last Theorem.
   - Generating functions and partitions.
   - Continued fractions.
   - Pell's equation.

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Recommended books
- B Burton “Elementary Number Theory” (Shelfmark 512.81 (B), ISBN 0071121749)
- B Rose “A Course in Number Theory”

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 4.
MAS331: Metric Spaces
Semester: 1 10 credits

Prerequisites: MAS221 (Analysis)
Corequisites:
Cannot be taken with:
Prerequisite for: MAS435 (Algebraic Topology); MAS436 (Functional Analysis)

Description
When working on the real line, as in MAS221, there is only one standard concept of convergence. This course studies convergence in the more general setting of a metric space, particularly the important cases of $\mathbb{R}^k$ and function spaces. A metric space is a set with a “distance function” which is governed by just three simple rules, from which the entire body of Analysis follows. The course follows on from MAS221 ‘Analysis’, and adapts some of the ideas from that course to the more general setting. The course includes the Contraction Mapping Theorem, which guarantees the convergence of quite general iterative processes; there are applications to many other areas of mathematics, such as to the existence of solutions to differential equations.

Aims
- To point out that iterative processes and convergence of sequences occur in many areas of mathematics, and to develop a general context in which to study these processes
- To provide a basic course in analysis in this setting
- To reinforce ideas of proof
- To illustrate the power of abstraction and show why it is worthwhile
- To provide a foundation for later analysis courses

Outline syllabus
- Metric spaces: definition, properties and examples
- Convergence of sequences
- Open and closed subsets
- Continuity
- Cauchy sequences, completeness
- Compactness
- Iteration and the Contraction Mapping Theorem

Module Format

| Lectures | 20 | Tutorials | 0 | Practicals | 0 |

Recommended books
- B Bryant “Metric Spaces: Iteration and Application” (Shelfmark 512.811 (B), ISBN 0521268575)
- C Kreyszig “Introductory Functional Analysis with Applications” (Shelfmark 517.5 (S), ISBN 0471507318)

Assessment
One formal 2.5 hour written examination. Format: 4 compulsory questions.
MAS332: Complex Analysis
Semester: 1 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with:
Prerequisite for: MAS430 (Analytic Number Theory); MAS436 (Functional Analysis)

Description
It is natural to use complex numbers in algebra, since these are the numbers we need to provide the roots of all polynomials. In fact, it is equally natural to use complex numbers in analysis, and this course introduces the study of complex-valued functions of a complex variable. Complex analysis is a central area of mathematics. It is both widely applicable and very beautiful, with a strong geometrical flavour. This course will consider some of the key theorems in the subject, weaving together complex derivatives and complex line integrals. There will be a strong emphasis on applications. Anyone taking the course will be expected to know the statements of the theorems and be able to use them correctly to solve problems.

Aims
- To introduce complex functions of a complex variable
- To demonstrate the critical importance of differentiability of complex functions of a complex variable, and its surprising relation with path-independence of line integrals
- To demonstrate the relevance of power series in complex analysis
- To develop the subject of complex analysis rigorously, highlighting its logical structure and proving several of the fundamental theorems
- To discuss some applications of the theory, including to the calculation of real integrals

Outline syllabus
- Revision of complex numbers
- Special functions
- Simple integrals of complex-valued functions
- Open sets, neighbourhoods and regions
- Differentiability; Cauchy-Riemann equations, harmonic functions
- Power series and special functions
- Complex line integrals
- Cauchy’s Theorem
- Cauchy’s integral formula and Cauchy’s formula for derivatives
- Taylor’s Theorem
- Laurent’s Theorem and singularities
- Cauchy’s Residue Theorem and applications

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Recommended books

B Priestley “Introduction to Complex Analysis” (Shelfmark 517.53 (P), ISBN 0198534299)
B Stewart and Tall “Complex Analysis” (Shelfmark 517.53 (S), ISBN 0521245133)
B Wunsch “Complex Variables with Applications” (ISBN 0201122995)
C Spiegel “Schaum’s Outline of Theory and Problems of Complex Variables” (Shelfmark 517.53 (S), ISBN 0070843821)

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 5.
MAS333: Fields
Semester: 1 10 credits

Prerequisites: MAS220 (Algebra)
Corequisites: Cannot be taken with: MAS438 (Fields)
Prerequisite for: Either this module or MAS438 (Fields) is needed for MAS442 (Galois Theory)

Description
A field is a set where the familiar operations of arithmetic are possible. It often happens, particularly in the theory of equations, that one needs to extend a field by forming a bigger one. The aim of this course is to study the idea of field extension and various problems where it arises. In particular, it is used to answer some classical problems of Greek geometry, asking whether certain geometrical constructions, such as angle trisection or squaring the circle, are possible.

Aims
- To illustrate how questions concerning the complex roots of real or rational polynomial equations can quickly lead to the study of subfields of the field of complex numbers
- To consolidate previous knowledge of field theory and vector space theory
- To illustrate how the general mathematical theory of vector spaces can be used to good effect in the theory of field extensions
- To illustrate how the theory of dimensions of vector spaces can be used to prove that certain ruler and compass constructions are impossible
- To illustrate the relevance of factorization of polynomials to the theory of algebraic field extensions

Outline syllabus
- Field extensions
- Factorization of polynomials
- Simple field extensions
- Towers of fields
- Ruler and compass constructions

Module Format
Lectures 20 | Tutorials 0 | Practicals 0

Recommended books
B Allenby “Rings, Fields and Groups” (Shelfmark 512.8 (A), ISBN 0340544406)
B Fraleigh “A First Course in Abstract Algebra” (Shelfmark 512.8 (F), ISBN 0201534673)
B Herstein “Abstract Algebra” (Shelfmark 512.8 (H), ISBN 0023538228)
B Stewart “Galois Theory” (Shelfmark 512.43 (S), ISBN 0412345404)

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 4.
Description
Combinatorics is the mathematics of selections and combinations. For example, given a collection of sets, when is it possible to choose a different element from each of them? That simple question leads to Hall’s Theorem, a far-reaching result with applications to counting and pairing problems throughout mathematics.

Aims
- To illustrate the wide range of selection problems in combinatorial mathematics
- To teach the basic techniques of selection and arrangement problems
- To show how to solve a wide range of natural counting problems using these techniques

Outline syllabus
- The binomial coefficients
- Three basic principles: parity, pigeon-holes and inclusion/exclusion
- Rook polynomials
- Hall’s Marriage Theorem and its applications
- Latin squares
- Block designs and codes

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Recommended books
- B Anderson “A First Course in Combinatorial Mathematics” (Shelfmark 519.21 (A), ISBN 0198596731)
- B Bryant “Aspects of Combinatorics” (Shelfmark 519.21 (B), ISBN 0521429978)

Assessment
One formal 2.5 hour examination. Format: answer all questions.
MA336: Differential Geometry
Semester: 1 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
Differential geometry is the study of geometric objects using calculus, and it has plenty of applications in other sciences and engineering. In this introductory course, the geometric objects of our interest will be curves and surfaces. You will learn more about such familiar notions as arc lengths, angles and areas. You will also learn how to quantify the “shape” of an object, via various notions of curvature. There are rich interactions between curvature and other geometric quantities, as illustrated most notably by Gauss’ Theorem. For example, we can make a map of the Earth that correctly represents either all angles or all areas; but by Gauss’ Theorem, the Earth’s curvature prevents us from ever making a map that correctly represents distances.

Aims
- to introduce differential geometry: its goals, techniques and applications;
- to translate intuitive ideas into mathematical concepts that allow quantitative studies and development of sophisticated results;
- to illustrate geometric concepts and results through many examples.

Outline syllabus
Curves in \( \mathbb{R}^2 \)
- Basic notions and examples
- Curvature
Surfaces in \( \mathbb{R}^3 \)
- Basic notions and examples
- Metric quantities
- Curvature
- Gauss’ Theorem

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Recommended books
- B Pressley “Elementary Differential Geometry” (Shelfmark 513.73 (P), ISBN 9781848828902)

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 4.
MAS341: Graph Theory
Semester: 2 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
A “graph” is a simple mathematical structure consisting of a collection of points (or vertices), some pairs of which are joined by lines. Their basic nature means that they can be used to illustrate a wide range of situations. The aim of this course is to investigate the mathematics of these structures and to use them in a wide range of applications. Topics covered include trees, Eulerian and Hamiltonian graphs, planar graphs, embedding of graphs in surfaces, and graph colouring.

Aims
- Gain a basic familiarity with graphs, their properties, and applications.
- Improve familiarity with proof in a concrete setting.
- Learn basic graph theoretic algorithms and their limitations.

Outline syllabus
- Introduction: handshaking, some applications, isomorphisms, trees, Hamiltonian and Eulerian graphs.
- Algorithms: shortest paths, cheapest spanning trees, and bounding the Travelling Salesman problem.
- Graph on surfaces: Planarity algorithm, Kuratowski’s and Euler’s Theorems.
- Colouring graphs: chromatic number, index, and polynomial.

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Recommended books

B Bryant “Aspects of Combinatorics” (Shelfmark 519.21 (B), ISBN 0521429978)
B Wilson “Introduction to Graph Theory” (Shelfmark 513.83 (W), ISBN 0582249937)
C Wilson “Four Colours Suffice” (Shelfmark 513.83 (W), ISBN 014100908x)

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 4.
MAS343: History of Mathematics
Semester: 2 10 credits

Prerequisites:
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
The course aims to introduce the student to the study of the history of mathematics. The main topics discussed are Egyptian and Babylonian mathematics, early Greek mathematics, Renaissance mathematics, and the early history of the calculus.

Aims
- To introduce the student to the history of mathematics
- To place mathematical developments into historical perspective
- To train the student to study from a set text
- To encourage independent study and use of the University’s libraries
- To allow students to research a topic and then write up a formal report or produce a poster on their findings, which counts towards the continuous assessment part of the course
- To discuss developments in mathematics in various periods, including its beginnings in the Egyptian and Mesopotamian civilizations, its flowering under the ancient Greeks and its renaissance in sixteenth-century Europe.
- To trace the pre-history of the calculus from its beginnings in Greece to its rapid expansion in seventeenth-century Europe.

Outline syllabus
- Introduction
- Egypt and Mesopotamia
- Early Greek mathematics
- Renaissance mathematics
- The route to the calculus

Module Format

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Recommended books

A Boyer and Merzbach “A History of Mathematics” (Shelfmark 510.9 (B), ISBN 0471543977)
B Katz “A History of Mathematics” (Shelfmark 510.9 (K), ISBN 0321016181)
C Fauvel and Gray “The History of Mathematics: A Reader” (Shelfmark 510.9 (H), ISBN 0333427912)

Assessment
One formal 2.5 hour written examination [69%]. Format: 1 compulsory question plus 3 questions from 4. Coursework [31%].
MAS344: Knots and Surfaces
Semester: 2 10 credits

Prerequisites: MAS114 (Numbers and Groups)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
The course studies knots, links and surfaces in an elementary way. The key mathematical idea is that of an algebraic invariant: the Jones polynomial for knots, and the Euler characteristic for surfaces. These invariants will be used to classify surfaces, and to give a practical way to place a surface in the classification. Various connections with other sciences will be described.

Aims
- To present a classification, that of compact surfaces, beginning from definitions and basic examples
- To instil an intuitive understanding of knots and compact surfaces
- To introduce and illustrate discrete invariants of geometric problems
- To show that adding extraneous structure may give information independent of that structure
- To develop the theory of the Euler characteristic
- To illustrate how a general mathematical theory can apply to quite different physical objects, and solve very specific problems about them

Outline syllabus
- Knots and links
- The Jones polynomial
- Surfaces
- The Euler characteristic

Module Format

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Recommended books
- Callier and Xu “A Guide to the Classification Theorem for Compact Surfaces”
- Comwell “Knots and Links”
C Firby and Gardiner “Surface Topology” (Shelfmark 513.83 (F), ISBN 1898563772)
C Gilbert and Porter “Knots and Surfaces” (Shelfmark 513.83 (G), ISBN 0198514905)
C Kauffman “On Knots” (Shelfmark 513.83 (K), ISBN 0691084351)

Assessment
One formal 2.5 hour written examination. Format: 4 compulsory questions.
MAS345: Codes and Cryptography
Semester: 2 10 credits

Prerequisites: MAS220 (Algebra);
MAS330 (Topics in Number Theory) (desirable)

Corequisites: Cannot be taken with:
Prerequisite for:

Description
The word ‘code’ is used in two different ways. The ISBN code of a book is designed in such a way that simple errors in recording it will not produce the ISBN of a different book. This is an example of an ‘error-correcting code’ (more accurately, an error-detecting code). On the other hand, we speak of codes which encrypt information — a topic of vital importance to the transmission of sensitive financial information across the internet. These two ideas, here labelled ‘Codes’ and ‘Cryptography’, each depend on elegant pure mathematical ideas: codes on linear algebra and cryptography on number theory. This course explores these topics, including the real-life applications and the mathematics behind them.

Aims
- To introduce the basic ideas connected with error detection and error correction, and various examples of useful codes
- To demonstrate the importance of the simple concepts of Hamming distance and the minimum distance of a code in the theory of error detection and error correction
- To illustrate how linear algebra can be used to good effect in the theory of linear codes
- To give an overview of cryptography from the most basic examples to modern public key systems
- To introduce the number-theoretic concepts used in public-key cryptosystems and to show how these are applied in practical examples

Outline syllabus
- Codes and linear codes
- Hamming distance
- Examples of error-correcting/error-detecting codes
- Classical methods of cryptography
- Results from number theory
- Public key methods of cryptography

Module Format

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Recommended books
- C Hill “A First Course in Coding Theory” (Shelfmark 003.54 (H), ISBN 0198538030)
- C Koblitz “A Course in Number Theory and Cryptography” (Shelfmark 512.81 (K), ISBN 0387942939)
- C Welsh “Codes and Cryptography” (Shelfmark 003.54 (W), ISBN 0198532873)
- C Young “Mathematical Ciphers: from Caesar to RSA” (ISBN 0821837303)

Assessment
One formal 2.5 hour written examination. Format: 4 compulsory questions, two on Codes and two on Cryptography.
MAS346: Groups and Symmetry
Semester: 2 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra); MAS220 (Algebra)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
Groups arise naturally as collections of symmetries. Examples considered include symmetry groups of Platonic solids and of wallpaper patterns. Groups can also act as symmetries of other groups. These actions can be used to prove the Sylow theorems, which give important information about the subgroups of a given finite group, leading to a classification of groups of small order.

Aims
- To consolidate previous knowledge of group theory, symmetries and linear algebra
- To display and exemplify the ubiquity of groups as symmetries of physical and mathematical objects
- To introduce and illustrate the process of analysis of a finite group from its local structure

Outline syllabus
- Orthogonal and special orthogonal symmetries of $\mathbb{R}^n$
- Group actions, Sylow theorems, and simple groups
- Symmetry and direct symmetry groups
- Affine isometries
- Wallpaper groups
- Groups of symmetries of the platonic solids
- Groups of small order

Module Format
Lectures 20 | Tutorials 0 | Practicals 0

Recommended books
B Armstrong “Groups and Symmetry” (Shelfmark 512.86 (A), ISBN 0387966757)
B Dummit “Abstract Algebra” (Shelfmark 512.8 (D), ISBN 0130047716)
B Fraleigh “A First Course in Abstract Algebra” (Shelfmark 512.8 (F), ISBN 0201534673)
B Herstein “Abstract Algebra” (Shelfmark 512.8 (H), ISBN 0023538228)
C Artin “Algebra” (Shelfmark 512 (A), ISBN 0130047635)

Assessment
One formal 2.5 hour written examination.
MAS348: Game Theory
Semester: 1 10 credits

Prerequisites: MAS113 (Introduction to Probability and Statistics) recommended; MAS211 (Advanced Calculus and Linear Algebra)

Corequisites: 
Cannot be taken with: ECN306 (Game Theory for Economists)
Prerequisite for: 

Description
The module will give students an opportunity to apply previously acquired mathematical skills to the study of Game Theory and to some of its applications in Economics.

Aims
• To understand the mathematical concept of a game and to see its manifestations in various real-life settings.
• To understand the notion of Nash equilibrium.
• To understand the technique of backward induction and its applications in the context of sequential games.
• To understand the notion of subgame-perfect Nash equilibria in sequential games.
• To understand the complexities of repeated games.
• To understand the concept of a Bayesian Game and their Nash equilibria.

Outline syllabus
• The formal definition of games both in strategic form and in sequential form.
• Solution of games by elimination of dominated strategies.
• Pure and mixed Nash equilibria of games.
• Nash Bargaining.
• Application of game theoretical techniques to solve real-life problems, e.g., in Economics.
• Solution of sequential games using backward induction.
• Translation games in normal form to sequential form and vice versa applying the concept of information sets and sub-game perfect Nash equilibria.
• Repeated games and their Nash equilibria.
• Bayesian games and their equilibria.

Module Format
| Lectures | 20 |
| Tutorials | 0 |
| Practicals | 0 |

Recommended books
B K.G. Binmore “Playing for Real: a Text on Game Theory” (Shelfmark 519.3 (B), ISBN 978-0195300574)
B M.J. Osborne “An Introduction to Game Theory” (Shelfmark 519.3(O), ISBN 9780195322484)

Assessment
One 2.5 hour exam.
MAS350: Measure and Probability
Semester: 2 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra); MAS221 (Analysis)
Corequisites:
Cannot be taken with: MAS451 (Measure and Probability)
Prerequisite for:

Description
Measure theory is that branch of mathematics which evolves from the idea of “weighing” a set by attaching a non-negative number to it which signifies its worth. This generalises the usual physical ideas of length, area and mass as well as probability. It turns out (as we will see in the course) that these ideas are vital for developing the modern theory of integration.

The module will give students an additional opportunity to develop skills in modern analysis as well as providing a rigorous foundation for probability theory. In particular it would form a useful precursor or companion course to the Level 4 courses MAS436 (Functional Analysis) and MAS452 (Stochastic Processes and Finance), the latter of which is fundamentally dependent on measure theoretic ideas.

Aims
- Give a more rigorous introduction to the theory of measure.
- Develop the ideas of Lebesgue integration and its properties.
- Recall the concepts of probability theory and consider them from a measure theoretic point of view.
- Prove the Central Limit Theorem using these methods.

Outline syllabus
- The scope of measure theory
- \( \sigma \)-algebras
- Properties of measures
- Measurable functions
- The Lebesgue integral
- Interchange of limit and integral
- Probability from a measure theoretic viewpoint
- Characteristic functions
- The central limit theorem

Module Format

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Recommended books
- C Williams “Probability With Martingales” (Shelfmark 519.236 (W), ISBN 0 521 40605 6)
- C Cohn “Measure Theory” (Shelfmark 3B 517.29 (C), ISBN 0-8176-3003-1)
- C Rosenthal “A First Look at Rigorous Probability ” (Shelfmark 519.2 (R), ISBN 081-02-4303-0)
- C Capinski and Kopp “Measure, Integral and Probability” (Shelfmark 517.29(C), ISBN 9781447106456)
- C Adams and Guillemin “Measure Theory and Probability” (Shelfmark 515.42(A), ISBN 9781461207795)

Assessment
One 2.5 hour exam.
MAS352: Stochastic Processes and Finance
Semester: Year 20 credits

Prerequisites: MAS113 (Introduction to Probability and Statistics);
MAS221 (Analysis);
MAS275 (Probability Modelling);
MAS223 (Statistical Inference and Modelling) recommended

Corequisites: Cannot be taken with: MAS452 (Stochastic Processes and Finance)
Prerequisite for: 

Description
Stochastic processes are models that reflect the wide variety of unpredictable ways in which reality behaves. In this course we study several examples of stochastic processes, and analyse the behaviour they exhibit. We apply this knowledge to mathematical finance, in particular to arbitrage free pricing and the Black-Scholes model.

Aims
- Introduce probability spaces, $\sigma$-fields and conditional expectation.
- Introduce martingales and study their basic properties.
- Analyse the behaviour of different types of stochastic process, such as random walks, urn models and branching processes.
- Explain the role of arbitrage and arbitrage free pricing.
- Use finite market models to price and hedge a range of financial derivatives.
- Introduce Brownian motion and study its basic properties.
- Introduce stochastic calculus, Ito’s formula and stochastic differential equations.
- Derive the Black-Scholes formula in continuous time and use it to price a range of financial derivatives.
- Study extensions of the Black-Scholes formula.

Outline syllabus
- Stochastic Processes: We introduce conditional expectation and martingales, which are used to study the behaviour of stochastic processes such as random walks, urn models, branching processes, Brownian motion and diffusions. Stochastic integration with respect to Brownian motion is introduced.
- Stochastic Finance: We study the key concept of arbitrage and arbitrage free pricing, both in finite markets and in the continuous time Black-Scholes model.

Module Format

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<td>Practicals</td>
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Recommended books
- C A Etheridge “A Course in Financial Calculus” (Shelfmark 332.0151922 (E), ISBN 0521890772)
- C T Björk “Arbitrage Theory in Continuous Time” (ISBN 9780199271269)
- C P Wilmott, S Howison, J Dewynne “The Mathematics of Financial Derivatives” (Shelfmark 332.64 (W), ISBN 0521496993)
- C D Williams “Probability with Martingales” (Shelfmark 519.236 (W), ISBN 0521406056)

Assessment
One formal 3 hour written closed book examination.
MAS360: Practical and Applied Statistics
Semester: Year 20 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites:
Cannot be taken with: MAS301 (Group Project)
Prerequisite for:

Description
This course aims to give you practice in solving problems of the sort you will encounter in real life as a professional mathematician or statistician. It gives training and practice in the various stages: problem definition, preliminary examination of data, modelling, analysis, computation, interpretation and communication of results. It is comprised of a series of exercises (not assessed) and projects (assessed). Teaching is directed towards skills development. Use of R for linear modelling is revised; specific guidance is given regarding presentation skills (oral and written) and group working; but no new technical material is taught. Instead, you are encouraged to recall and collate the technical material gained over the entire remainder of your degree programme and to identify and implement those methods which are appropriate and useful in addressing the problem at hand. This vital skill, of synthesizing and evaluating your existing knowledge, allows you to show yourself at your best in examinations, interviews and the early days of a future career.

Aims
- To develop students’ skills in open-ended tasks with a substantial statistical aspect.
- To develop students’ abilities to report on the results of their investigations.

Outline syllabus
There is no technical syllabus for this course; indeed it is deliberately arranged that no new theory is needed, although students may need to use extended versions of familiar topics or invent ad hoc methods. Instruction is given in writing reports and in tackling imprecisely worded or open-ended problems. Feedback on projects attempted continues this instruction.

Module Format

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Recommended books
- There are no recommended books for this course.

Assessment
Entirely continuous assessment, through project reports and presentations. The weighting and deadlines will be announced during the module.
MAS361: Medical Statistics

Semester: 1 10 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites: Cannot be taken with: MAS61002 (Medical Statistics)

Description

This course comprises sections on Clinical Trials and Survival Data Analysis. The special ethical and regulatory constraints involved in experimentation on human subjects mean that Clinical Trials have developed their own distinct methodology. Students will, however, recognise many fundamentals from mainstream statistical theory. The course aims to discuss the ethical issues involved and to introduce the specialist methods required. Prediction of survival times or comparisons of survival patterns between different treatments are examples of paramount importance in medical statistics. The aim of this course is to provide a flavour of the statistical methodology developed specifically for such problems, especially with regard to the handling of censored data (e.g., patients still alive at the close of the study). Demonstrating implementation of the statistical analyses in the R package is an important part of the course.

Aims

- To illustrate applications of statistics within the medical field.
- To introduce students to some of the distinctive statistical methodologies developed to tackle problems specifically related to clinical trials and the analysis of survival data.

Outline syllabus

- **Clinical Trials:**
  - Basic concepts and designs: controlled and uncontrolled clinical trials; historical controls; protocol; placebo; randomisation; blind and double blind trials; ethical issues; protocol deviations.
  - Size of trials.
  - Multiplicity and meta-analysis: interim analyses; multi-centre trials; combining trials.
  - Cross-over trials.
  - Binary response data: logistic regression modelling; McNemar’s test, relative risks, odds ratios.

- **Survival Data Analysis:**
  - Basic concepts: survivor function; hazard function; censoring.
  - Single sample methods: lifetables; Kaplan-Meier survival curve; parametric models.
  - Two sample methods: log-rank test; parametric comparisons.
  - Regression models: inclusion of covariates; Cox’s proportional hazards model; parametric and accelerated failure time regression models.

Module Format

| Lectures | 18 | Tutorials | 2 | Practicals | 0 |

Recommended books

- A Everitt and Rabe-Heskith “Analyzing Medical Data Using S-Plus” (Shelfmark 610.285 (E))
- A Matthews “An Introduction to Randomized Controlled Clinical Trials” (Shelfmark 615.50724)
- B Altman “Practical Statistics for Medical Research” (Shelfmark 519.023 (A), ISBN 1584880392)
- B Campbell "Statistics at Square Two" (Shelfmark 519.023 (C), ISBN 1405134909)
- B Collett “Modelling Survival Data in Medical Research” (Shelfmark 610.727 (C), ISBN 1584883251)

Assessment

One formal 2 hour written examination. Format: 3 questions from 4.
MAS362: Financial Mathematics
Semester: 1 10 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites:
Cannot be taken with: MAS462 (Financial Mathematics)
Prerequisite for:

Description
The discovery of the Capital Asset Pricing Model by William Sharpe in the 1960’s and the Black-Scholes option pricing formula a decade later mark the beginning of a very fruitful interaction between mathematics and finance. The latter obtained new powerful analytical tools while the former saw its knowledge applied in new and surprising ways. (A key result used in the derivation of the Black-Scholes formula, Ito’s Lemma, was first applied to guide missiles to their targets; hence the title ‘rocket science’ applied to financial mathematics). This course describes the mathematical ideas behind these developments together with their applications in modern finance.

Aims
• To introduce students to the mathematical ideas and methods used in finance.
• To familiarise students with financial instruments such as shares, bonds, forward contracts, futures and options.
• To familiarise students with the notion of arbitrage and the notion of no-arbitrage pricing.
• To introduce the binomial tree and geometric Brownian motion models for stock prices.
• To familiarise students with the Black-Scholes option pricing method.
• To introduce the Capital Asset Pricing Model.

Outline syllabus
• Introduction, arbitrage, forward and futures contracts
• Options, binomial trees, risk-neutral valuation
• Brownian motion and share prices, the Black-Scholes analysis
• Portfolio theory, the Capital Asset Pricing Model

Module Format

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Recommended books

- B Capinski and Zastawniak “Mathematics for Finance: An Introduction to Financial Engineering” (Shelfmark 332.0151 (C), ISBN 1852333308)
- B Hull “Options, Futures and Other Derivatives” (Shelfmark 332.645 (H), ISBN 0131499084)
- B Sharpe “Portfolio Theory and Capital Markets” (Shelfmark 332.6 (S), ISBN 0071353208)

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 4.
MAS364: Bayesian Statistics
Semester: 1 10 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites: Cannot be taken with: MAS61006 (Bayesian Statistics and Computational Methods)
Prerequisite for:

Description
This unit develops the Bayesian approach to statistical inference. The Bayesian method is fundamentally different in philosophy from conventional frequentist/classical inference, and has been the subject of some controversy in the past. It is, however, becoming increasingly popular in many fields of applied statistics. This course will cover both the foundations of Bayesian statistics, including subjective probability, inference, and modern computational tools for practical inference problems, specifically Markov Chain Monte Carlo methods and Gibbs sampling. Applied Bayesian methods will be demonstrated in a series of case studies using the software package R.

Aims
- To extend understanding of the practice of statistical inference.
- To familiarize the student with the Bayesian approach to inference.
- To describe computational implementation of Bayesian analyses.

Outline syllabus
- Subjective probability.
- Predictive inference.
- Hierarchical models.

Module Format

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Recommended books

- DeGroot and Schervish “Probability and Statistics”
- Gelman, Carlin, Stern and Rubin “Bayesian Data Analysis” (Shelfmark 519.42 (W), ISBN 0412039915)
- Lee “Bayesian Statistics: An Introduction” (Shelfmark 519.542 (L), ISBN 0340814055)
- Spiegelhalter, Abrams, and Myles “Bayesian Approaches to Clinical Health-care Evaluation”

Assessment
One formal 2 hour written examination [85%]. Format: 3 questions from 4. Continuous assessment [15%].
**MAS369: Machine Learning**
Semester: 1 10 credits

Prerequisites:  **MAS223** (Statistical Inference and Modelling)
Corequisites:  
Cannot be taken with:  **MAS61007** (Machine Learning)
Prerequisite for:  

**Description**

Machine learning lies at the interface between computer science and statistics. The aims of machine learning are to develop a set of tools for modelling and understanding complex data sets. Tools of statistical machine learning have become important in many fields, such as marketing, finance and business, as well as in science. The module focuses on the problem of training models to learn from existing data to classify new examples of data. Although other aspects of machine learning will be mentioned, the module focuses on the problem of classification; other topics in machine learning are covered by modules in Computer Science.

**Aims**

- Introduce students to the main problems in machine learning
- Introduce students to some of the techniques used for solving problems in data science
- Introduce students to neural networks and the main ideas behind “deep learning”
- Introduce students to the principal computer packages involved in machine learning

**Outline syllabus**

- The main problems of data science and machine learning
- Data sets and data visualisation
- Dimensionality reduction – principal components analysis and introduction to other methods
- Supervised learning: the classification problem and discriminant analysis
- Regression and classification trees
- Ensemble methods and random forests; boosting
- Support vector machines
- Neural networks and deep learning

**Module Format**

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**Recommended books**

- C James, Witten, Hastie and Tibshirani, “An Introduction to Statistical Learning” from [http://www-bcf.usc.edu/~gareth/ISL/](http://www-bcf.usc.edu/~gareth/ISL/)

**Assessment**

Two projects of equal weight.
**MAS370: Sampling Theory and Design of Experiments**

Semester: 2  10 credits

Prerequisites:  
MAS223 (Statistical Inference and Modelling);

Corequisites:  

Cannot be taken with:  
MAS61003 (Sampling Theory and Design of Experiments)

Prerequisite for:  

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**Description**

The results of sample surveys through opinion polls are commonplace in newspapers and on television. The objective of the Sampling Theory section of the module is to introduce several different methods for obtaining samples from finite populations. Experiments which aim to discover improved conditions are commonplace in industry, agriculture, etc. The purpose of experimental design is to maximise the information on what is of interest with the minimum use of resources. The aim of the Design section is to introduce some of the more important design concepts.

**Aims**

- To consolidate some previous mathematical and statistical knowledge.
- To introduce statistical ideas used in sample surveys and the design of experiments.

**Outline syllabus**

This course deals with two different areas where the important features are the planning before the data are collected, and the methods for maximising the information which will be obtained. The results of sample surveys through opinion polls, etc., are commonplace in newspapers and on television. The Sampling Theory component of the course introduces several different methods for obtaining samples from finite populations and considers which method is most appropriate for a given sampling problem. Experiments which aim to discover improved conditions are commonplace in industry, agriculture, etc. The purpose of experimental design is to maximise the information on what is of interest with the minimum use of resources. The Experimental Design component of the course introduces some of the more important design concepts.

**Module Format**

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**Recommended books**

- **B** Barnett “Sample Survey: Principles and Methods” (Shelfmark 519.6 (B), ISBN 0340763981)
- **B** Box, Hunter and Hunter “Statistics for Experimenters: Design, Innovation, and Discovery” (Shelfmark 519.5(B), ISBN 9780471718130)
- **B** Morris “Design of Experiments: an Introduction Based on Linear Models” (Shelfmark 001.434 (M), ISBN 9781584889236)
- **C** Atkinson and Donev “Optimum Experimental Designs” (Shelfmark 519.52 (A), ISBN 019929660X)
- **C** Box and Draper “Empirical Model Building and Response Surfaces” (Shelfmark 519.52 (B), ISBN 0471810339)
- **C** Cornell “Experiments with Mixtures” (Shelfmark 519.52 (C), ISBN 0471393673)
- **C** Cox and Reid “The Theory of the Design of Experiments” (Shelfmark 519.52 (C), ISBN 158488195X)
- **C** Goos and Jones “Optimal Design of Experiments : A Case Study Approach” (Shelfmark 670.285 (G), ISBN 9780470744611)

**Assessment**

One formal 2 hour written examination. Exam format: all questions compulsory.
MAS371: Applied Probability
Semester: 2 10 credits

Prerequisites: MAS223 (Statistical Inference and Modelling);
               MAS275 (Probability Modelling)

Corequisites:
Cannot be taken with:
Prerequisite for:

Description
This unit will link probability modelling to statistics. It will explore a range of models that can be constructed for random phenomena that vary in time or space - the evolution of an animal population, for example, or the number of cancer cases in different regions of the country. It will illustrate how models are built and how they might be applied: how likelihood functions for a model may be derived and used to fit the model to data, and how the result may be used to assess model adequacy. Models examined will build on those studied in MAS275.

Aims
- Illustrate the construction of probability models for random phenomena;
- Introduce some of the common classes of models for random phenomena;
- Illustrate how probability models may be fitted to data;
- Discuss applications of fitted models.

Outline syllabus
- Basic techniques: likelihood functions and their properties and use.
- Continuous time Markov chains: Introduction; generator matrices; informal coverage of stationary distributions and convergence.
- Inference for stochastic processes: deriving likelihood functions for stochastic processes; fitting models to data; model criticism.
- Applications of Markov chains: birth-death processes; queues.
- Point processes: homogeneous and inhomogeneous Poisson processes, spatial and marked point processes, inference for point processes.

Module Format
Lectures 20 | Tutorials 0 | Practicals 0

Recommended books
C Bailey “The Elements of Stochastic Processes with Applications to the Natural Sciences” (Shelfmark 519.31 (B))
C Grimmett and Stirzaker “Probability and Random Processes” (Shelfmark 519.2 (G), ISBN 0198572239)
C Guttorp “Stochastic Modeling of Scientific Data” (Shelfmark 519.23 (G), ISBN 0412992817)
C Renshaw “Modelling Biological Populations in Space and Time” (Shelfmark 574.55 (R), ISBN 0521448557)
C Taylor and Karlin “An Introduction to Stochastic Modelling” (Shelfmark 519.2 (T), ISBN 0126848874)

Assessment
One 2 hour written examination.
**MAS372: Time Series**

Semester: 2  10 credits

**Prerequisites:** MAS223 (Statistical Inference and Modelling)

**Corequisites:**

**Cannot be taken with:** MAS61005 (Time series)

**Prerequisite for:**

**Description**

Time series are observations made in time, for which the time aspect is potentially important for understanding and use. The course aims to give an introduction to modern methods of time series analysis and forecasting as applied in economics, engineering and the natural, medical and social sciences. The emphasis will be on practical techniques for data analysis, though appropriate stochastic models for time series will be introduced as necessary to give a firm basis for practical modelling. For the implementation of the methods the programming language R will be used.

**Aims**

- To introduce methods to uncover structure in series of observations made through time.
- To illustrate how models for time series may be constructed and studied.
- To develop methods to analyse and forecast time series.
- To show how these methods are applied to data, and what kinds of conclusion are possible.

**Outline syllabus**

- Approaches to time series analysis. Simple descriptive methods: smoothing, decomposition.
- State space models. Filtering (Kalman filter), smoothing and forecasting.
- Trend and seasonal state space models, time-varying regression. Estimation of hyperparameters, error analysis.

**Module Format**

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**Recommended books**

- **A** Brockwell and Davies “Introduction to Time Series and Forecasting” (Shelfmark 519.36 (B), ISBN 0387953515)
- **A** Shumway and Stoffer “Time Series Analysis and its Applications : With R Examples” (Shelfmark 519.55 (S) , ISBN 0387293175)
- **B** Chatfield “The Analysis of Time Series : An Introduction” (Shelfmark 519.55 (C) , ISBN 1584883170)
- **B** West and Harrison “Bayesian Forecasting and Dynamic Models” (Shelfmark 519.42 (W), ISBN 0387947256)

**Assessment**

One formal 2 hour written examination. Format: 3 questions from 3.
MAS377: Mathematical Biology
Semester: 1 10 credits

Prerequisites: MAS222 (Differential Equations)
Corequisites: Cannot be taken with:
Prerequisite for:

Description
The course provides an introduction to the mathematical modelling of the dynamics of biological populations. The emphasis will be on deterministic models based on systems of differential equations that encode population birth and death rates. Examples will be drawn from a range of different dynamic biological populations, from the species level down to the dynamics of molecular populations within cells. Central to the course will be the dynamic consequences of feedback interactions within the populations. In cases where explicit solutions are not readily obtainable, techniques that give a qualitative picture of the model dynamics (including numerical simulation) will be used.

Aims
To introduce students to the applications of mathematical techniques in deterministic models for the dynamics of biological populations.

Outline syllabus
- Population models: Deterministic models; birth and death processes; logistic growth; competition between populations.
- Epidemic models: Compartment models; the SIR model.
- Biochemical and Genetic Networks: Mass-action kinetics; simple genetic circuits; genetic switches and clocks.

Module Format

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Recommended books

B J M Murray “Mathematical Biology” (Shelfmark 570.15118 (M), ISBN 9780387952239)
B Ellner and Guckenheimer “Dynamic Models in Biology” (Shelfmark 570.15118 (E), ISBN 9780691125893)
C van den Berg “Mathematical Models of Biological Systems” (Shelfmark 570.15118 (B), ISBN 9780199982181)

Assessment
One formal 2 hour written examination.
MAS400: Project Presentation in Mathematics and Statistics
Semester: 1 10 credits

Prerequisites:
Corequisites: MAS406 (Mathematics and Statistics Project)
Cannot be taken with: MAS301 (Group Project) simultaneously
Prerequisite for:

Description
This unit provides further training and experience in the use of appropriate computer packages for the presentation of mathematics and statistics, and guidance on the coherent and accurate presentation of technical information.

Aims
- To develop written skills for use in the level 4 project.
- To develop oral skills for use in the level 4 project.
- To develop general presentational skills usable in a wider context.

Outline syllabus
- Review of LATEX and TeXworks
- Typesetting mathematics in LATEX
- Writing mathematics and statistics
- Structuring a mathematical report
- Oral presentations
- The LATEX beamer package

Module Format

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Recommended books
- LATEX wikibook
- Higham “Writing for the Mathematical Sciences” (Shelfmark 808.06651 (H))

Assessment
Coursework [65%]. Oral presentation [35%].
MAS406: Mathematics and Statistics Project
Semester: Year 30 credits

Prerequisites:
Corequisites: MAS400 (Project Presentation in Mathematics and Statistics)
Cannot be taken with:
Prerequisite for:

Description
The student selects a project topic offered by a member of staff and writes a project on this under the supervision of the member of staff.

Aims
• To give students experience of, and training in, research and presentation of an advanced mathematical topic
• To support the development of independent study skills
• To support the acquisition of communication and presentation skills
• To provide an introduction to the research experience
• To give the opportunity to study a specialist topic of attraction to the student

Outline syllabus
There is no recorded outline syllabus for this module.

Module Format

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Recommended books
• There are no recommended books for this course.

Assessment
30–40 page dissertation [90%]. Oral presentation [10%].
MAS411: Topics in Advanced Fluid Mechanics
Semester: 1 20 credits

Prerequisites:
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
This module aims to describe advanced mathematical handling of fluid equations in an easily accessible fashion. A number of topics are treated in connection with the mathematical modelling of the formation of the (near-)singular structures with concentrated vorticity in inviscid flows. After discussing prototype problems in one and two dimensions, three-dimensional flows in terms of vortex dynamics are described. Mathematical tools are explained during the unit in a self-contained manner. Candidates are directed to read key original papers on some topics to deepen their understanding.

Aims
This unit aims to familiarise candidates with advanced mathematical techniques used in fluid mechanics, in particular in vortex dynamics, by working out prototype problems. The mathematical tools we will learn as we go include: the heat kernel for the diffusion equation, Hilbert transforms, methods of complex functions, Fourier series, Taylor series in time, transformation by stretched-coordinates and method of linear stability analysis.

Outline syllabus
- Fluid dynamical equations revisited
- 1D model equations
- Vortex sheet problem
- Vortex patch problem
- 3D Euler equations
- 3D Navier-Stokes equations

Module Format
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Recommended books
- C Majda and Bertozzi “Vorticity and Incompressible Flow” (Shelfmark 532.56 (M), ISBN 0521639484)
- C Saffman “Vortex Dynamics” (Shelfmark 532.595 (S), ISBN 0521477395)

Assessment
One formal 2.5-hour written examination [80%]. Format: 4 questions from 5. Students will also be required to complete derivations from approx. 5 papers on a reading list [20%].
Newton formulated his famous laws of mechanics in the late 17th century. Only later it became obvious through the work of mathematicians like Lagrange, Hamilton and Jacobi that underlying Newton’s work are wonderful mathematical structures. In the first semester, the work of Lagrange, Hamilton and Jacobi will be discussed and how it has later affected the formulation of field theory. We will also discuss Noether’s theorem, which relates symmetries of a system to the conservation law of certain quantities (such as energy and momentum). In the second semester, Einstein’s theory of gravity, General Relativity, will be introduced. The physical principles of General Relativity and mathematical concepts from differential geometry presented. Some consequences of this theory, such as black holes and the expanding universe, will be discussed.

Aims
- to introduce students to the formulations of mechanics by Lagrange and Hamilton;
- to show how mechanical problems can be formulated in much simpler ways;
- introduce new mathematical methods: calculus of variations and canonical transformations;
- show how relativistic systems can be described in the formalisms of Lagrange and Hamilton;
- introduce the concept of a field and how the ideas of Lagrange and Hamilton can be extended to describe fields such as the gravitational field and the electromagnetic field;
- show how Noether’s theorem relates the conservation of quantities like energy and momentum to symmetries in Nature;
- to introduce students to the theory of General Relativity;
- to show how methods and concepts of differential geometry are used in General Relativity;
- to show some consequences of Einstein’s theory (black holes and the expanding universe).

Outline syllabus
- Formulations of Lagrange and Hamilton;
- Calculus of variations and canonical transformations;
- Interpretation of relativistic systems in the formalisms of Lagrange and Hamilton;
- Fields;
- Noether’s theorem;
- Physical Principles of General Relativity;
- Mathematical concepts from Differential Geometry;
- The Schwarzschild Spacetime;
- The Robertson-Walker-Friedmann Spacetime

Module Format

| Lectures | 40 |
| Tutorials | 0 |
| Practicals | 0 |

Recommended books
- C Goldstein, Poole, Safko “Classical Mechanics” (Shelfmark 531 (G), ISBN 0321188977)
- C Joel Franklin “Advanced Mechanics and General Relativity” (ISBN 0521762456)
- C Morin “Introduction to Classical Mechanics” (ISBN 0521876222)
- C Sean Carroll “Spacetime and Geometry: An Introduction to General Relativity” (ISBN 1292026634)

Assessment
One formal 3 hour written examination.
MAS414: Mathematical Modelling of Natural Systems
Semester 2  10 credits

Prerequisites:  MAS212 (Scientific Computing and Simulation) Please contact lecturers if you did not take this module; MAS222 (Differential Equations)
Corequisites: Cannot be taken with:  MAS316 (Mathematical modelling of natural systems)

Description
Mathematical modelling enables insight into a wide range of scientific problems. This module will provide a practical introduction to techniques for modelling natural systems. Students will learn how to construct, analyse and interpret mathematical models, using a combination of differential equations, scientific computing and mathematical reasoning. Students will learn the art of mathematical modelling: translating a scientific problem into a mathematical model, identifying and using appropriate mathematical tools to analyse the model, and finally relating the significance of the mathematical results back to the original problem. Study systems will be drawn from throughout the environmental and life sciences.

Aims
- develop students’ skills in comprehending problems, formulating them mathematically and obtaining solutions by appropriate methods;
- provide practical demonstrations of how mathematical modelling may be used to gain insight into the dynamics of natural systems;
- build on mathematical methods (ordinary/partial differential equations, linear stability analysis, scientific computing in Python) learned at earlier levels, and expose students to how they can be used to model natural systems.

Outline syllabus
- An introduction to chaotic dynamics.
- Spatial pattern formation in biology.
- Machine learning methods to retrieve forest biophysical parameters.

Module Format

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Recommended books
- Murray JD “Mathematical Biology I and II” (Shelfmark 570.15118 (M), ISBN 978-0-387-22437-4 and 978-0-387-22438-1)
- Strogatz SH “Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering” (Shelfmark 531.3 (S), ISBN 9780738204536)

Assessment
Three pieces of coursework and one oral presentation, with no examination.
MAS420: Signal Processing
Semester 1  10 credits

Prerequisites:  MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
The transmission, reception and extraction of information from signals is an activity of fundamental importance. This course describes the basic concepts and tools underlying the discipline, and relates them to a variety of applications. An essential concept is that a signal can be decomposed into a set of frequencies by means of the Fourier transform. From this grows a very powerful description of how systems respond to input signals. Perhaps the most remarkable result in the course is the celebrated Shannon-Whittaker sampling theorem, which tells us that, under certain conditions, a signal can be perfectly reconstructed from samples at discrete points. This is the basis of all modern digital technology.

Aims
- To develop the idea that a signal can be treated as a set of frequencies by using the Fourier transform.
- To exploit this representation to give fundamental insight into how systems act on signals.
- To demonstrate that a continuous (analog) signal can be sampled to produce a discrete (digital) signal, without any loss of information, as long as the signal contains only a finite range of frequencies.
- To convey the immense importance of these ideas to modern life.

Outline syllabus
- Signals in Hilbert space.
- The Fourier Series.
- The Fourier Transform and its properties.
- Convolution, energy and bandwidth.
- Delta functions.
- Linear shift invariant (LSI) systems.
- The Shannon-Whittaker sampling theorem.

Module Format
Lectures  20  |  Tutorials  0  |  Practicals  0

Recommended books
B  Baher  “Analog and Digital Signal Processing” (Shelfmark 621.3822 (B), ISBN 0471623547)
B  Oppenheim and Willsky  “Signals and Systems” (Shelfmark 621.38223 (O), ISBN 0136511759)
B  Stremler  “Introduction to Communication Systems” (Shelfmark 621.382 (S), ISBN 0201516519)

Assessment
One formal 2 hour written examination. Format: 4 questions from 4.
MAS422: Magnetohydrodynamics
Semester 2 10 credits

Prerequisites: MAS222 (Differential Equations); MAS280 (Mechanics and Fluids)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
Magnetohydrodynamics has been successfully applied to a number of astrophysical problems (e.g., to problems in Solar and Magnetospheric Physics), as well as to problems related to laboratory physics, especially to fusion devices. This module gives an introduction to classical magnetohydrodynamics. Students will get familiar with the system of magnetohydrodynamic equations and main theorems that follow from this system (e.g., conservation laws, anti-dynamo theorem). They will study the simplest magnetic equilibrium configurations, propagation of linear waves, and magnetohydrodynamic stability.

Aims
- To introduce the system of magnetohydrodynamic equations.
- To describe the main properties of this system of equations.
- To show using simple examples how this system of equations can be applied to different astrophysical and laboratory phenomena.

Outline syllabus
- The system of magnetohydrodynamic equations and its main properties.
- Magnetohydrodynamics equilibria.
- Propagation of magnetohydrodynamic waves.
- Magnetohydrodynamic stability.
- Magnetic dynamo.

Module Format

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Recommended books
- B Goedbloed and Poedts “Principles of Magnetohydrodynamics” (Shelfmark 538.6 (G), ISBN 9027718334)
- B Goossens “Introduction to Plasma Astrophysics and Magnetohydrodynamics” (Shelfmark 523.2 (G), ISBN 1402014333)
- B Priest “Solar Magneto-hydrodynamics” (Shelfmark 523.72 (P), ISBN 9027718334)

Assessment
One formal 2 hour written examination. Format: 4 questions.
MAS423: Advanced Operations Research
Semester 2 10 credits

Prerequisites: MAS211 (Advanced Calculus and Linear Algebra)
Corequisites:
Cannot be taken with: MAS322 (Operations Research)
Prerequisite for:

Description
Mathematical Programming is the title given to a collection of optimisation algorithms that deal with constrained optimisation problems. Here the problems considered will all involve constraints which are linear, and for which the objective function to be maximised or minimised is also linear. Some of these problems are not continuously differentiable; special algorithms have to be developed. The module considers first how these problems arise from practical applications, then introduces the solution of such problems, and finally explain the important area of post-optimality analysis where we answer questions about the effects of changes in the parameters of the problem on the optimal solution. Additional topics include integer programming problems and network models.

Aims
- To develop the mathematical skills that will provide you with the appropriate foundations for further mathematical studies.
- To enable you to analyse OR problems that may arise in your future employment.

Outline syllabus
- Building linear programming, integer programming and piecewise linear programming models
- Graphical techniques
- The Simplex Method and variants
- Matrix representation of the simplex algorithm
- Elementary post-optimality analysis
- Duality

Module Format
Lectures 20 | Tutorials 1 | Practicals 0

Recommended books
- B Paul R. Thie and Gerard E. Keough “An Introduction to Linear Programming and Game Theory” (Shelfmark 518.7 (T))
- B Taha “Operations Research: An Introduction” (Shelfmark 519.38 (T), ISBN 0131889230)
- C Bertsimas and Tsitsiklis “Introduction to Linear Optimization.” (Shelfmark 519.72 (B), ISBN 1886529191)
- C Winston “Introduction to Mathematical Programming” (Shelfmark 519.7 (W), ISBN 0534359647)

Assessment
One formal 2 hour written examination with 4 compulsory questions [65%]. Mini-project [35%].
MAS430: Analytic Number Theory
Semester 1  10 credits

Prerequisites:  MAS114 (Numbers and Groups); MAS332 (Complex Analysis)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
Analytic number theory aims to study number theory by using analytic tools (inequalities, limits, calculus, etc). In this course we will mainly focus on studying the distribution of prime numbers by using analysis. Perhaps it is surprising that such a link even exists!

We will try and give precise answers to questions such as; Roughly how big is the \( n \)th prime? Approximately how many primes are less than a given number? How fast does the sequence of primes diverge to infinity? Is there always a prime between \( n \) and \( 2n \)?

A big result to be proved in the course is Dirichlet’s theorem on primes in arithmetic progressions. This tells us that for coprime \( a, b \) the sequence \( an + b \) contains infinitely many primes. The general proof of this result features a unique blend of algebra and analysis and was the cornerstone of 19th century number theory.

Aims
- To illustrate how general methods of analysis can be used to obtain results about integers and prime numbers
- To investigate the distribution of prime numbers
- To consolidate earlier knowledge of analysis through applications

Outline syllabus
- Distribution of primes
- Implications of the Prime Number Theorem
- Dirichlet series
  - The Riemann zeta function
  - Dirichlet’s Theorem on primes in arithmetic progression

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Recommended books

B Apostol “Introduction to analytic number theory” (Shelfmark 512.81 (A), ISBN 0387901639)
B Davenport “Multiplicative number theory” (Shelfmark 512.81 (D), ISBN 0387950974)

Assessment

One formal 2.5 hour written examination. Format: 4 questions, answer all.
MAS435: Algebraic Topology
Semester Year 20 credits

Prerequisites: MAS220 (Algebra); MAS331 (Metric Spaces)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description

In this course, we will study geometric objects from a topological point of view. This means we will be not be interested in the exact shape of a space or the distances between points, but rather the properties that are preserved under stretching. We will show how to capture these properties purely in terms of open sets, giving the notion of topological space. Our examples will include balls, spheres, surfaces, the $n$-holed torus, the Möbius strip, the Klein bottle, other surfaces, knots, projective spaces.... We will define what it means for two spaces to be homeomorphic, but the focus will be on properties preserved by much more radical sorts of change (i.e., homotopy equivalence).

We will study a number of algebraic invariants (i.e. ways to associate algebraic objects to topological ones in which homotopy equivalent spaces give isomorphic algebraic objects). For each one, we need to show how to construct the invariant and how to calculate it. It then follows that if the algebraic objects associated to two spaces are not isomorphic, then the spaces are not homotopy equivalent.

The first invariant we consider is the fundamental group: this is a group constructed from a space by looking at loops in the space. It captures geometry in a rather accessible way, but is generally hard to calculate. On the other hand, the homology groups capture higher dimensional information, and are easier to calculate but harder to define. Once these invariants are defined we will calculate them for a range of spaces and give a variety of applications: Brouwer and Lefschetz fixed point theorems, hairy ball theorem, Ham Sandwich Theorem, Football Squashing Theorem, proof of the Fundamental Theorem of Algebra,

Note that one of the suggested books is available online free from http://pi.math.cornell.edu/~hatcher/AT/ATpage.html

Aims

- To teach the basic ideas of topological spaces, the fundamental group and homology.
- To illustrate these ideas by reference to a range of examples, including surfaces.
- To show how to calculate fundamental groups, chain complexes and homology of various topological spaces.

Outline syllabus

Part A

1. Introduction and motivation
2. Simplicial complexes
3. Topological spaces
4. Homeomorphism
5. Paths
6. Categories and functors
7. Cutting invariants
8. Constructing new spaces
9. The Hausdorff property, and compactness
10. Homotopy
11. The fundamental group

Part B

12. Covering maps
13. Applications of the fundamental group
14. Neighbourhoods of subcomplexes
15. The van Kampen Theorem
16. Abelian groups
17. Chain complexes and homology
18. The chain complex of a simplicial complex
19. Chain homotopy
20. The Snake Lemma
21. The Mayer-Vietoris Theorem
22. Subdivision
23. Simplicial approximation

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Recommended books

- **B** Armstrong “Basic Topology” (Shelfmark 513.83 (A), ISBN 0-387-90839-0)
- **B** Fulton “Algebraic Topology: A First Course” (Shelfmark 514.2 (F), ISBN 3-540-94327-7)
- **B** Hatcher “Algebraic Topology [free download from author’s webpage]” (Shelfmark 513.83 (H), ISBN 0521795400)

Assessment

There will be eight homework assignments in each semester. The best five in each semester will each count for 2% of the overall course grade, making 20% in total. The remaining 80% will be based on a final exam. This will be an open book exam with a nominal length of 1.5 hours. There will be two questions, and you should attempt both of them. More detailed arrangements will be circulated closer to the time.
Functional analysis is the study of infinite-dimensional vector spaces equipped with extra structure. Such spaces arise naturally as spaces of functions. As well as being a beautiful subject in its own right, functional analysis has numerous applications in other areas of both pure and applied mathematics, including Fourier analysis, study of the solutions of certain differential equations, stochastic processes, and in quantum physics. In this unit we focus mainly on the study of Hilbert spaces- complete vector spaces equipped with an inner product- and linear maps between Hilbert spaces. Applications of the theory considered include Fourier series, differential equations, index theory, and the basics of wavelet analysis.

Aims

- To introduce students to the ideas and some of the fundamental theorems of functional analysis.
- To show students the use of abstract algebraic/topological structures in studying spaces of functions.
- To allow students to taste the subject with a view to further work as a postgraduate.
- To give students a working knowledge of the basic properties of Banach spaces, Hilbert spaces and bounded linear operators.
- To show students the idea of duals and adjoints.
- To show students the value of looking at the spectrum of a bounded linear operator.
- To demonstrate significant applications of the theory of functional analysis.

Outline syllabus

- Normed and Banach Spaces
- Linear Maps and Continuity
- Spaces of Continuous Functions
- Hilbert Spaces
- Orthonormal Sets
- Spectral Theory
- Fredholm Operators
- Wavelets

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Recommended books

- C Debnath and Mikusinski “Introduction to Hilbert Spaces with Applications” (Shelfmark 515.733 (D), ISBN 0122084381)
- C Kreyszig “Introductory Functional Analysis with Applications” (Shelfmark 517.5 (S), ISBN 0471504599)
- C Rynne and Youngson “Linear functional analysis” (ISBN 9781848000049)

Assessment

One formal 2.5 hour written examination.
MAS438: Fields
Semester 1 10 credits

Prerequisites: MAS220 (Algebra)
Corequisites: 
Cannot be taken with: MAS333 (Fields)
Prerequisite for: 

Description
A field is a set where the familiar operations of arithmetic are possible. It often happens, particularly in the theory of equations, that one needs to extend a field by forming a bigger one. The aim of this course is to study the idea of field extension and various problems where it arises. In particular, it is used to answer some classical problems of Greek geometry, asking whether certain geometrical constructions, such as angle trisection or squaring the circle, are possible. The finite fields and their groups of automorphisms are studied.

Aims
- To illustrate how questions concerning the complex roots of real or rational polynomial equations can quickly lead to the study of subfields of the field of complex numbers
- To consolidate previous knowledge of field theory and vector space theory
- To illustrate how the general mathematical theory of vector spaces can be used to good effect in the theory of field extensions
- To illustrate how the theory of dimensions of vector spaces can be used to prove that certain ruler and compass constructions are impossible
- To illustrate the relevance of factorization of polynomials to the theory of algebraic field extensions
- To study the finite fields and their groups of automorphisms

Outline syllabus
- Field extensions
- Factorization of polynomials
- Simple field extensions
- Towers of fields
- Ruler and compass constructions
- Finite fields and their groups of automorphisms
- The algebraic closure of a finite field
- The Frobenius automorphism

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Recommended books
- B Allenby “Rings, fields and groups” (Shelfmark 512.8 (A), ISBN 0340544406)
- B Fraleigh “A first course in abstract algebra” (Shelfmark 512.8 (F), ISBN 0201534673)
- B Herstein “Abstract algebra” (Shelfmark 512.8 (H), ISBN 0023538228)
- B Stewart “Galois theory” (Shelfmark 512.43 (S), ISBN 0412345404)

Assessment
One formal 2.5 hour written examination. Format: 4 questions from 4.
MAS439: Commutative Algebra and Algebraic Geometry
Semester Year 20 credits

Prerequisites: MAS220 (Algebra)
Corequisites: 
Cannot be taken with: 
Prerequisite for: 

Description
This module will develop both the algebraic and geometric theories of commutative rings and modules. The most basic form of interaction between these two subjects can be seen as the relationship between polynomials and their graphs. This relationship can then be extended to the relationship between ideals in polynomial rings and the corresponding vanishing loci in affine space. At a basic level, this module is about turning algebra into pictures and describing pictures using algebra. To do so, we will study many important properties of commutative rings and their modules, and then explore the geometric counterparts of these properties. Interpreted in the context of the complex numbers, this analogy between algebra and geometry reflects many of the basic intuitions one has about graphs of polynomial equations. Once the basic dictionary is set up however, it can be applied in more exotic situations, such as over finite fields.

Aims
• To establish a basic groundwork of knowledge in commutative algebra.
• To apply that knowledge to study problems of a geometric nature.
• To develop an appropriate perspective on the techniques discussed.
• To understand the connections between algebra and geometry.

Outline syllabus

Part A
• Definition of a ring and examples
• Homomorphisms and subrings
• Ideals and quotient rings
• Algebras and polynomials
• Noetherian rings
• Algebraic subsets
• Statement of Hilbert’s Nullstellensatz
• Affine varieties
• Regular maps
• Localization

Part B
• Modules, isomorphism theorems
• Localization for modules
• Nakayama’s Lemma
• Integral extensions
• Noether normalization
• Proof of Nullstellensatz
• Further topics

Module Format

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Recommended books

B Atiyah and Macdonald “Introduction to commutative algebra” (Shelfmark 512.8 (A), ISBN 0201407515)
B Eisenbud “Commutative algebra with a view toward algebraic geometry” (Shelfmark 512.8 (E), ISBN 0387942696)
B Reid “Undergraduate algebraic geometry” (Shelfmark 513.6 (R), ISBN 0521356628)
B Reid “Undergraduate commutative algebra” (Shelfmark 512.8 (R), ISBN 0521458897)
B Sharp, Rodney Y. “Steps in Commutative Algebra” (ISBN 512.44 (S))

Assessment

Assessment will be via 10 problem sheets, assigned fortnightly through both semesters. The final mark will depend only on the sum of the 10 marks received for these assignments. The problems will assess the student’s knowledge of the key concepts, their ability to synthesize and generalize these concepts, and their ability to present proofs logically and coherently. Clear standards and sample solutions will be provided to students at the beginning of the module.
MAS442: Galois Theory
Semester 2 10 credits

Prerequisites: MAS333 (Fields) or MAS438 (Fields)
Corequisites: Cannot be taken with:
Prerequisite for:

Description
Given a field $K$ (as studied in MAS333/438) one can consider the group $G$ of isomorphisms from $K$ to itself. In the cases of interest, this is a finite group, and there is a tight link (called the Galois correspondence) between the structure of $G$ and the subfields of $K$. If $K$ is generated over the rationals by the roots of a polynomial $f(x)$, then $G$ can be identified as a group of permutations of the set of roots. One can then use the Galois correspondence to help find formulae for the roots, generalising the standard formula for the roots of a quadratic. It turns out that this works whenever the degree of $f(x)$ is less than five. However, the fifth symmetric group lacks certain group-theoretic properties that lie behind these formulae, so there is no analogous method for solving arbitrary quintic equations. The aim of this course is to explain this theory, which is strikingly rich and elegant.

Aims
- To explain the general theory of homomorphisms between fields.
- To explain the definition of Galois groups, and to compute them for cyclotomic extensions, and various extensions of small degree.
- To explain the Galois correspondence, and use it to reduce various questions in field theory to easier questions about finite groups.
- To study splitting fields and Galois theory for cubics and quartics, and to explain how they lead to algorithms for finding roots.

Outline syllabus
- Review of fields and other background
- Homomorphisms and field extensions
- Splitting fields
- Extending homomorphisms; normal field extensions; Galois groups
- Examples involving extensions of small degree
- Cyclotomic fields and their Galois groups
- Finite fields (if time permits)
- The Galois correspondence
- Cubics and quartics
- Extension by radicals and solvability.

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Recommended books

- B Edwards “Galois theory” (Shelfmark 512.81 (E), ISBN 038790980X)
- B Escofier “Galois theory” (Shelfmark 512.81 (E), ISBN 0387987657)
- B Garling “A course in Galois theory” (Shelfmark 512.81 (G), ISBN 0521312493)
- B Rotman “Galois theory” (Shelfmark 512.81 (R), ISBN 0387985417)
- B Stewart “Galois theory” (Shelfmark 512.43 (S), ISBN 1584883936)
- C King “Beyond the quartic equation” (Shelfmark 512.3 (K), ISBN 0817637761)

Assessment

One formal 2.5 hour written examination. All questions compulsory.
MAS451: Measure and Probability
Semester 2 10 credits

Prerequisites: MAS221 (Analysis)
Corequisites:
Cannot be taken with: MAS350 (Measure and Probability)
Prerequisite for:

Description
The module will give students an additional opportunity to develop skills in modern analysis as well as providing a rigorous foundation for probability theory. In particular it would form a companion course to MAS436 (Functional Analysis) and MAS452 (Stochastic Processes and Finance), the latter of which is fundamentally dependent on measure theoretic ideas.

Aims
- give a more rigorous introduction to the theory of measure.
- develop the ideas of Lebesgue integration and its properties.
- recall the concepts of probability theory and consider them from a measure theoretic point of view.
- prove the Strong Law of Large Numbers and the Central Limit Theorem using these methods.

Outline syllabus
- The scope of measure theory,
- $\sigma$-algebras,
- Properties of measures,
- Measurable functions,
- The Lebesgue integral,
- Interchange of limit and integral,
- Probability from a measure theoretic viewpoint,
- Characteristic functions,
- The central limit theorem.

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Recommended books
C M.Capinski and E.Kopp “Measure, Integral and Probability” (Shelfmark 517.29(C), ISBN 1-85233-781-8)

Assessment
One 2 hours 30 minutes exam.
MAS452: Stochastic Processes and Finance
Semester Year 20 credits

Prerequisites: MAS113 (Introduction to Probability and Statistics); MAS221 (Analysis); MAS223 (Statistical Inference and Modelling) [recommended]; MAS275 (Probability Modelling)
Corequisites: Cannot be taken with: MAS352 (Stochastic Processes and Finance)
Prerequisite for: 

Description
Stochastic processes are models that reflect the wide variety of unpredictable ways in which reality behaves. In this course we study several examples of stochastic processes, and analyze the behavior they exhibit. We apply this knowledge to mathematical finance, in particular to arbitrage free pricing and the Black-Scholes model.

Aims
- Introduce probability spaces, $\sigma$-fields and conditional expectation.
- Introduce martingales and study their basic properties.
- Analyse the behaviour of different types of stochastic process, such as random walks, urn models and branching processes.
- Explain the role of arbitrage and arbitrage free pricing.
- Use finite market models to price and hedge a range of financial derivatives.
- Introduce Brownian motion and study its basic properties.
- Introduce stochastic calculus, Ito's formula and stochastic differential equations.
- Derive the Black-Scholes formula in continuous time and use it to price a range of financial derivatives.
- Study extensions of the Black-Scholes model.
- Use branching processes to model debt contagion.

Outline syllabus
- Stochastic Processes: We introduce conditional expectation and martingales, which are used to study the behavior of stochastic processes such as random walks, urn models, branching processes, Brownian motion and diffusions. Stochastic integration with respect to Brownian motion is introduced.
- Stochastic Finance: We study the key concept of arbitrage and arbitrage free pricing, both in finite markets and in the continuous time Black-Scholes model. We also introduce the idea of modelling debt contagion using branching processes.

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Recommended books

C Bjork, T “Arbitrage Theory in Continuous Time” (ISBN 9780199271269)
C Etheridge, A. “A Course in Financial Calculus” (Shelfmark 332.0151922 (E), ISBN 0521890772)
C Williams, D. “Probability with Martingales” (Shelfmark 519.236 (W), ISBN 0521406056)

Assessment
One three hour closed book exam.
**MAS462: Financial Mathematics**  
Semester 1  
10 credits

**Prerequisites:** MAS223 (Statistical Inference and Modelling)  
**Corequisites:**  
**Cannot be taken with:** MAS362 (Financial Mathematics)  
**Prerequisite for:**

### Description

The discovery of the Capital Asset Pricing Model by William Sharpe in the 1960’s and the Black-Scholes option pricing formula a decade later mark the beginning of a very fruitful interaction between mathematics and finance. The latter obtained new powerful analytical tools while the former saw its knowledge applied in new and surprising ways. (A key result used in the derivation of the Black-Scholes formula, Ito’s Lemma, was first applied to guide missiles to their targets; hence the title ‘rocket science’ applied to financial mathematics). This course describes the mathematical ideas behind these developments together with their applications in modern finance, and includes a computational project where students further explore some of the ideas of option pricing.

### Aims

- To introduce students to the mathematical ideas and methods used in finance.  
- To familiarise students with financial instruments such as shares, bonds, forward contracts, futures and options.  
- To familiarise students with the notion of arbitrage and the notion of no-arbitrage pricing.  
- To introduce the binomial tree and geometric Brownian motion models for stock prices.  
- To familiarise students with the Black-Scholes option pricing method.  
- To introduce the Capital Asset Pricing Model.

### Outline syllabus

- Introduction, arbitrage, forward and futures contracts  
- Options, binomial trees, risk-neutral valuation  
- Brownian motion and share prices, the Black-Scholes analysis  
- Portfolio theory, the Capital Asset Pricing Model.

### Module Format

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### Recommended books

- **Capinski and Zastawniak** “Mathematics for Finance: An Introduction to Financial Engineering” (Shelfmark 332.0151 (C), ISBN 1852333308)  
- **Hull** “Options, futures and other derivatives” (Shelfmark 332.645 (H), ISBN 0131499084)  
- **Sharpe** “Portfolio theory and capital markets” (Shelfmark 332.6 (S), ISBN 0071353208)

### Assessment

One formal 2.5 hour written examination [70%]. Format: 4 questions from 4. Project [30%].
MAS61001: Generalised Linear Models
Semester 2 15 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites:
Cannot be taken with: MAS31001 (Generalised Linear Models)
Prerequisite for:

Description
This module introduces the theory and application of generalised linear models (GLMs). Such models can be used for modelling binary or count data, where the dependent variable is not normally distributed; this increases the range of problems that can be studied substantially. The general theory will be presented, in which the ordinary linear model is a special case. Application of the methods will be demonstrated using R, including the use of exploratory data analysis methods as a precursor to modelling.

Aims
• introduce the theory of generalised linear models.
• show how these methods are applied to data, and what kinds of conclusions are possible.
• demonstrate how generalised linear models can be fitted to data using R.
• enhance students’ broader understanding of statistical methodology and develop their professional skills as applied statisticians.

Outline syllabus
• Introducing generalised linear models: theoretical concepts;
• Binomial, ordinal, multinomial and Poisson regression;
• Incorporating mixed effects in linear and generalised linear models;
• implementation with R.

Module Format
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Recommended books
B Faraway “Extending the linear model with R: Generalized linear, Mixed Effects and Nonparametric Regression models (Second edition)”

Assessment
One formal 2 hour examination [70%]. Project [30%].
MAS61002: Medical Statistics
Semester Year 15 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites: Cannot be taken with: MAS361 (Medical Statistics)
Prerequisite for:

Description
This module comprises sections on Clinical Trials and Survival Data Analysis. The special ethical and regulatory constraints involved in experimentation on human subjects mean that Clinical Trials have developed their own distinct methodology. Students will, however, recognise many fundamentals from mainstream statistical theory. The course aims to discuss the ethical issues involved and to introduce the specialist methods required. Prediction of survival times or comparisons of survival patterns between different treatments are examples of paramount importance in medical statistics. The aim of this course is to provide a flavour of the statistical methodology developed specifically for such problems, especially with regard to the handling of censored data (e.g., patients still alive at the close of the study). Demonstrating implementation of the statistical analyses in the R package is an important part of the course.

Aims
- To illustrate applications of statistics within the medical field.
- To introduce students to some of the distinctive statistical methodologies developed to tackle problems specifically related to clinical trials and the analysis of survival data.
- To demonstrate how appropriate statistical methods for analysing clinical trial data can be implemented using the software package R.
- To enhance students’ broader understanding of statistical methodology and develop their professional skills as applied statisticians.

Outline syllabus
Clinical Trials:
- Basic concepts and designs: controlled and uncontrolled clinical trials; historical controls; protocol; placebo; randomisation; blind and double blind trials; ethical issues; protocol deviations.
- Size of trials.
- Multiplicity and meta-analysis: interim analyses; multi-centre trials; combining trials.
- Cross-over trials.
- Binary response data: logistic regression modelling; McNemar’s test, relative risks, odds ratios.

Survival Data Analysis:
- Basic concepts: survivor function; hazard function; censoring.
- Single sample methods: lifetables; Kaplan-Meier survival curve; parametric models.
- Two sample methods: log-rank test; parametric comparisons.
- Regression models: inclusion of covariates; Cox’s proportional hazards model; parametric and accelerated failure time models.

Module Format
- Lectures 20
- Tutorials 0
- Practicals 0

Recommended books
A Everitt and Rabe-Heskith “Analyzing Medical Data Using S-Plus” (Shelfmark 610.285 (E), ISBN 0387988629)
A Matthews “An Introduction to Randomized Controlled Clinical Trials” (Shelfmark 615.50724 (M), ISBN 1584886242)
B Altman “Practical Statistics for Medical Research” (Shelfmark 519.023 (A), ISBN 1584880392)
B Campbell “Statistics at Square Two” (Shelfmark 519.023 (C), ISBN 1405134909)
B Collett “Modelling Survival Data in Medical Research” (Shelfmark 610.727 (C), ISBN 1584883251)
Assessment

One formal 2 hour written examination [70%]. Project [30%].
**MAS61003: Sampling Theory and Design of Experiments**

Semester 2 15 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)

Corequisites: Cannot be taken with: MAS370 (Sampling Theory and Design of Experiments)

**Description**

This module deals with two different areas where the important features are the planning before the data are collected, and the methods for maximising the information which will be obtained. The results of sample surveys through opinion polls, etc., are common in the media. The Sampling Theory component of the course introduces several different methods for obtaining samples from finite populations and considers which method is most appropriate for a given sampling problem. Experiments which aim to discover improved conditions are common in industry, agriculture, etc. The purpose of experimental design is to maximise the information on what is of interest with the minimum use of resources. The Experimental Design component of the course introduces some of the more important design concepts. The module also introduces the concept of a 'computer experiment' (as opposed to a physical experiment), and considers the problem of uncertainty in predictions from computer models.

**Aims**

- introduce statistical ideas used in sample surveys.
- introduce statistical methods for the design of physical experiments, in particular where the analysis can be performed using linear modelling techniques.
- introduce statistical methods for the design and analysis of computer experiments.
- enhance students' broader understanding of statistical methodology and develop their professional skills as applied statisticians.

**Outline syllabus**

- Methods for selecting samples in sample surveys.
- Statistical inference for finite populations.
- Experimental design for linear models. Optimal designs and factorial experiments.
- Uncertainty and sensitivity analysis for computer model predictions.

**Module Format**

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**Recommended books**

- B Barnett “Sample Survey; Principles and Methods” (Shelfmark 519.6 (B), ISBN 0340763981)
- B Box, Hunter and Hunter “Statistics for experimenters: design, innovation, and discovery” (Shelfmark 519.5(B), ISBN 9780471718130)
- B Morris “Design of experiments: an introduction based on linear models” (Shelfmark 001.434 (M), ISBN 9781584889236)
- C Atkinson and Donev “Optimum Experimental Designs” (Shelfmark 519.52 (A), ISBN 019929660X)
- C Box and Draper “Empirical model building and response surfaces” (Shelfmark 519.52 (B), ISBN 0471810339)
- C Cornell “Experiments with mixtures” (Shelfmark 519.52 (C), ISBN 0471393673)
- C Cox and Reid “The theory of the design of experiments” (Shelfmark 519.52 (C), ISBN 158488195X)
- C Goos and Jones “Optimal design of experiments : a case study approach” (Shelfmark 670.285 (G), ISBN 9780470744611)
**Assessment**

One formal 2 hour examination [100%].
MAS61005: Time Series
Semester 2 15 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Corequisites:
Cannot be taken with: MAS372 (Time series)
Prerequisite for:

Description
Time series are observations made sequentially in time, where an observation at one time point may be
dependent on observations at previous time points. The course aims to give an introduction to modern
methods of time series analysis and forecasting as applied in economics, engineering and the natural, medical
and social sciences. The emphasis will be on practical techniques for data analysis, though appropriate
stochastic models for time series will be introduced as necessary to give a firm basis for practical modelling.
For the implementation of the methods the programming language R will be used.

Aims
• introduce methods to uncover structure in series of observations made through time;
• illustrate how models for time series may be constructed and studied, and how forecasts can be obtained;
• demonstrate the application of time series analysis and forecasting methods using R;
• enhance students' broader understanding of statistical methodology and develop their professional skills
  as applied statisticians.

Outline syllabus
• Examples of time series. Purposes of analysis. Components (trend, cycle, seasonal, irregular). Station-
  arity and autocorrelation.
• Approaches to time series analysis. Simple descriptive methods: smoothing, decomposition.
• Moving average models. Partial autocorrelation. Invertibility. ARMA processes.
• ARIMA models for non-stationary series. Identification and fitting. Diagnostics. Ljung-Box statistic,
  introduction to forecasting.
• State space models. Filtering (Kalman filter), smoothing and forecasting.
• Trend and seasonal state space models, time-varying regression. Estimation of hyperparameters, error
  analysis.

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Recommended books

A Brockwell and Davies “Introduction to Time Series and Forecasting” (Shelfmark 519.36 (B), ISBN
0387953515)

A Shumway and Stoffer “Time Series Analysis and its Applications : With R Examples” (Shelfmark 519.55
(S), ISBN 0387293175)

B Chatfield “The Analysis of Time Series : An Introduction” (Shelfmark 519.55 (C) , ISBN 1584883170)

B West and Harrison “Bayesian Forecasting and Dynamic Models” (Shelfmark 519.42 (W), ISBN 0387947256)

Assessment
One formal written examination (70%). All questions compulsory. One project (30%)
MAS61006: Bayesian Statistics and Computational Methods
Semester Year 30 credits

Prerequisites: MAS223 (Statistical Inference and Modelling)
Coresquisites:
Cannot be taken with: MAS364 (Bayesian Statistics)
Prerequisite for:

Description
This module first introduces the Bayesian approach to statistical inference, presenting the foundations, applications in simple settings (using “conjugate priors”), and computational methods using Markov chain Monte Carlo. In parallel, students will also learn R programming, with a focus on implementing various Monte Carlo methods. In semester 2, students will study further computational methods which can be used for implementing various statistical inferential procedures. More complex Bayesian models will also be presented, which will provide motivation for the computational methods taught. Students will learn how to implement Markov chain Monte Carlo methods using the probabilistic programming language “Stan”.

Aims
- introduce the Bayesian approach to statistical inference.
- present a range of computational tools for implementing Bayesian and frequentist inference, in otherwise intractable problems.
- demonstrate how various computational methods and be implemented using R and Stan.
- enhance students’ broader understanding of statistical methodology and develop their professional skills as applied statisticians.

Outline syllabus
- Bayesian inference; analysis with conjugate priors;
- Markov chain Monte Carlo methods, including Hamiltonian Monte Carlo implemented with Stan;
- Other Monte Carlo computational methods, e.g. bootstrapping;
- R programming.

Module Format
Lectures 40  Tutorials 0  Practicals 8

Recommended books
B Gelman, Carlin, Stern and Rubin “Bayesian Data Analysis” (Shelfmark 519.42 (W), ISBN 0412039915)
B Lee “Bayesian Statistics: An Introduction” (Shelfmark 519.542 (L), ISBN 0340814055)

Assessment
One formal 3 hour written examination (60%). All questions compulsory. One project (40%).
**MAS61007: Machine Learning**
Semester 1 15 credits

**Prerequisites:** MAS223 (Statistical Inference and Modelling)
**Corequisites:**
**Cannot be taken with:** MAS369 (Machine Learning)
**Prerequisite for:**

**Description**
Machine learning lies at the interface between computer science and statistics. The aims of machine learning are to develop a set of tools for modelling and understanding complex data sets. Tools of statistical machine learning have become important in many fields, such as marketing, finance and business, as well as in science. The module focuses on the problem of training models to learn from existing data to classify new examples of data. Although other aspects of machine learning will be mentioned, the module focuses on the problem of classification; other topics in machine learning are covered by modules in Computer Science.

**Aims**
- Introduce students to the main problems in machine learning
- Introduce students to some of the techniques used for solving problems in data science
- Introduce students to neural networks and the main ideas behind “deep learning”
- Introduce students to the principal computer packages involved in machine learning

**Outline syllabus**
- The main problems of data science and machine learning
- Data sets and data visualisation
- Dimensionality reduction – principal components analysis and introduction to other methods
- Supervised learning: the classification problem and discriminant analysis
- Regression and classification trees
- Ensemble methods and random forests; boosting
- Support vector machines
- Logistic regression, neural networks and deep learning

**Module Format**

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**Recommended books**
- C Everitt “An R and S-PLUS Companion to Multivariate Analysis”
- C Hastie, Tibshirani and Friedman “The Elements of Statistical Learning”
- C James, Witten, Hastie and Tibshirani “An Introduction to Statistical Learning”

**Assessment**
Two projects of equal weight.
PHY421: Advanced Particle Physics
Semester: 2 10 credits

Prerequisites: MAS314 (Introduction to Relativity)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
The module provides students with a comprehensive understanding of modern particle physics. Focussing on the standard model, it provides a theoretical underpinning of this model and discusses its predictions. Recent developments, including the discovery of the Higgs boson and neutrino oscillation studies, are covered. A description of the experiments used to probe the standard model is provided. Finally the module looks at possible physics beyond the standard model.

Aims
To give students:

- An understanding of the historical development of particle physics.
- An understanding of the standard model of particle physics.
- Familiarity with the experimental techniques used to probe the standard model.
- An understanding of the requirement for the Higgs boson.
- An understanding of the physics of neutrino mixing.
- Familiarity with current theories of physics beyond the standard model.

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Recommended books

A Bettini "Introduction to Elementary Particle Physics" (Shelfmark: Ebook)
A Thomson "Modern Particle Physics" (Shelfmark 539.72 (T))

Assessment
One formal 2 hour written examination [85%]. Coursework [15%].
PHY472: Advanced Quantum Mechanics
Semester: 1 10 credits

Prerequisites: MAS324 (Quantum Theory)
Corequisites:
Cannot be taken with:
Prerequisite for:

Description
In this course, we will build quantum mechanics from the ground up, starting with linear vector spaces and Hilbert space. We introduce the postulates of quantum mechanics and explore important topics in modern quantum mechanics such as mixed states, decoherence, entanglement, and quantum teleportation. We also give a thorough treatment of spin and orbital angular momentum. In the second part, we look at many body problems in quantum mechanics. We explore the physics of identical particles, and apply this theory to many-electron atoms, spin waves in solids, and atoms in an optical cavity. Finally, we will briefly introduce the basic principles behind quantum field theory.

Aims
- To teach some of the more advanced theoretical concepts and techniques in quantum mechanics. The topics covered include the Hilbert space formalism, mixed states versus pure states and non-unitary evolution, entanglement and teleportation, spin and orbital angular momentum.

Outline syllabus
- Linear Vector Spaces and Hilbert Space.
- The Postulates of Quantum Mechanics.
- Schrödinger and Heisenberg Pictures.
- Mixed States and the Density Operator.
- Composite Systems and Entanglement.
- Evolution of Open Quantum Systems.
- Orbital Angular Momentum and Spin.
- Many-body quantum physics.

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Recommended books

C Schumacher and Westmoreland “Quantum Processes, Systems, and Information” (Shelfmark 530.12 (S), ISBN 9780521875349)

Assessment

One formal 3 hour written examination.