MMathPhys/MSc in Mathematical and Theoretical Physics Handbook (2025-26 Entry)

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Prelude

ISSUED SEPTEMBER 2025

THE HANDBOOK WILL NOT BE CONSIDERED FINALISED UNTIL IT HAS PASSED THE APPROVAL OF THE JOINT SUPERVISORY COMMITTEE.

This handbook applies to students studying the MMathPhys/MSc Mathematical and Theoretical Physics degree in the 2025-2026 academic year. The information in this handbook may be different for students starting in other years.

The Examination Regulations relating to this course are available at:

https://examregs.admin.ox.ac.uk/.

If there is a conflict between the information in this handbook and the Examination Regulations then you should follow the Examinations Regulations.

Please consider this a draft, until otherwise notified by the course administrator. While the current information is provided for students' benefit, and is generally accurate, it is not officially confirmed as the final version until it is reviewed and approved by the Joint Supervisory Committee for the course in week 3 of Michaelmas Term.

It may be necessary, under exceptional circumstances, to publish further changes to the course details at a later date. If such changes are made, the department will publish a new version of this handbook together with a list of the changes and students will be informed. For details, please see https://www.ox.ac.uk/admissions/graduate/courses/changes-to-courses

If you have any concerns please contact:

mathematical.physics@maths.ox.ac.uk

Welcome

Welcome to the Oxford Master's Course in Mathematical and Theoretical Physics. Our course provides a high-level education in the areas of Theoretical Particle Physics/String Theory, Condensed Matter Theory, Theoretical Astrophysics/Fluids and Mathematical Foundations of Theoretical Physics up to the level of research.

As you are probably aware, there is considerable flexibility in designing your path through the course; you can decide to focus on one of the above subject areas or study a broader span across areas. It is important that you consider your choices carefully. Consult the syllabi and case studies in this handbook for more information and, if in doubt, talk to your personal tutor or an academic related to the programme.

For an advanced programme of this kind, written examinations are not always the best form of assessment. You will find that the way we evaluate your work often correlates with the nature of the material. Typically, there will be formal written exams for the basic, foundational courses; other forms of assessment such as take-home exams or mini-projects for intermediate courses, and a home-work completion requirement for advanced courses. There are certain constraints on assessment — for example you have to sit four units of written exams. Be sure that your course choices are consistent with these constraints. Also note that Trinity term is devoted to advanced courses and there is no designated "revision" period.

Passing exams is a necessary and important part of learning and education but we hope you agree that there is significantly more to it. Enthusiasm, engagement with the subject, the desire for deep and profound understanding is what truly motivates us and we hope this is how you will engage with the course. We wish you a successful, productive and insightful year.

Best wishes,

Prof Caroline Terquem and Prof Lionel Mason

1. Introduction

This handbook contains important information about the Master's Course in Mathematical and Theoretical Physics. It is intended as a guide and reference for you throughout the course. There are a number of other sources of information that you will need to refer to during your course and links to these are given in the following section.

1.1 Key Sources of Information

Course website: http://mmathphys.physics.ox.ac.uk/

Mathematical Institute website: http://www.maths.ox.ac.uk/

Department of Physics website: http://www.physics.ox.ac.uk/

Examination Regulations: https://examregs.admin.ox.ac.uk/

The University's examination regulations govern all academic matters within the University and contain the general regulations for the conduct of University examinations, as well as specific regulations for each degree programme offered by the University)

Examination Conventions: http://mmathphys.physics.ox.ac.uk/students

The examination conventions for the course set out how each unit will be assessed and how the final degree classification will be derived from the marks obtained for the individual units.

Oxford student website: http://www.ox.ac.uk/students

Oxford Student Handbook: https://www.ox.ac.uk/students/academic/student-handbook

This contains general information and guidance about studying at the University of Oxford, and gives you formal notification and explanation of the University's codes, regulations, policies and procedures.

College Handbook: The handbook for your college will be available on the college website.

1.2 Key Contacts

Course Director, Prof Lionel Mason, lionel.mason@maths.ox.ac.uk

Chair of the Joint Supervisory Committee, Prof Caroline Terquem, caroline.terquem@physics.ox.ac.uk

Course Administrator, Eleanor Kowol, mmathphys@maths.ox.ac.uk

Mathematical Institute Reception: reception@maths.ox.ac.uk

Department of Physics Reception: reception@physics.ox.ac.uk

1.3 Maps

In-person teaching for the course will take place in the Mathematical Institute and in the Denys Wilkinson Building or in the Clarendon Laboratory of the Department of Physics.

To enter the Denys Wilkinson Building, go up the wide concrete steps from Keble Road; turn left at the top and the entrance is facing you:
https://www.accessguide.ox.ac.uk/denys-wilkinson-building

The main entrance to the Clarendon Laboratory is on Parks Road, next to the University Parks: https://www.accessguide.ox.ac.uk/clarendon-laboratory

At the Mathematical Institute, all lecture rooms and classrooms are located on the mezzanine level. http://www.maths.ox.ac.uk/about-us/travel-maps

The building has been designed with accessibility in mind. More details of the disability policy and the access guide are given at https://www.maths.ox.ac.uk/members/building-information/accessibility

A searchable, interactive map of all college, department and libraries can be found at https://maps.ox.ac.uk/

1.4 Buddy System

All MSc students will be buddied by an internal 4th year MMathPhys student, who has transferred from MMath/MPhys or MMathPhil undergraudate at Oxford, to help integrate the MSc students to the university and department. We try to pair people from the same college, or a nearby college though this is not always possible. MSc students will receive their buddy's college e-mail address and they can arrange to meet and seek advice about aspects of student life which interest them such as exams, social events or courses.

1.5 The Academic Year

The academic year at Oxford is in three terms, named Michaelmas, Hilary and Trinity terms. You will often see these written as MT, HT and TT.

Each term has 8 weeks. Weeks are counted from Sunday, not Monday. So that the first day of week 1 would be Sunday, 12th October 2025.

There is also a 0th week, which is not included in the published term dates, as no teaching takes place. In Michaelmas term, 0th week is akin to an induction or 'freshers' week, with many induction talks and events happening in departments and colleges.

In Hilary and Trinity terms, written exams are scheduled in 0th week (as well as further exams later in term), so you should return to Oxford the week *before* term starts to sit exams.

The term dates for the academic year 2025-2026, *not including 0th weeks,* are as follows:

Term	Start Date	End Date
Michaelmas	Sunday, 12th October 2025	Saturday, 6th December 2025
Hilary	Sunday, 18th January 2026	Saturday, 14th March 2026
Trinity	Sunday, 26th April 2026	Saturday, 20th June 2026

Note, many timetables, emails and schedules will refer to dates by week number, not by the Gregorian calendar date,

> ***e.g. 'the lecture on Bosons is rescheduled to Tue, Week 4.'***

You might even see a week written as 4 MT for '4th week Michaelmas term' or the terms MT25, HT26, TT26 to indicate the term *and* year.

1.6 Resources and Facilities

Departmental Work and Social Spaces

You will be able to use the computers and desks in the Mezzanine Study Room to work within the Mathematical Institute. The study room has power sockets for students wishing to use their own laptops and there is wi-fi throughout the building.

The Institute's café is also located on the mezzanine level and has seating and tables for 100. The café serves drinks, snacks and meals from 08.30am - 4pm, Monday -Friday.

The menu for each week can be found here: https://estates.admin.ox.ac.uk/sitefiles/beyond-ordinary-cafe-menu-andrew-wiles-cafe-p

The Denys Wilkson building's café is open 10am - 2pm, Monday-Friday. Menu here: https://estates.admin.ox.ac.uk/sitefiles/beyond-ordinary-cafe-menu-denys.pdf

Departmental Safety Policies

You are urged to act at all times responsibly, and with a proper care for your own safety and that of others. Departmental statements of safety policy are posted in all departments, and you must comply with them. Students should note that they (and others entering onto departmental premises or who are involved in departmental activities) are responsible for exercising care in relation to themselves and others who may be affected by their actions.

In the Mathematical Institute accidents should be reported immediately to reception, telephone 73525, who keep the accident book. There is a first aid room located on the ground floor of the South wing. If you require access to this room please report to reception. Each lecture theatre has its own proper escape route and you are urged to familiarise yourself with these. Those for the Mathematical Institute lecture and seminar rooms are set out online:

http://www.maths.ox.ac.uk/members/building-information/security-safety-and-reporting-building-issues.

Libraries

The main source of borrowed books is your own College library. You will also have access to the Radcliffe Science Library (RSL) on Parks Road.

Website: https://www.bodleian.ox.ac.uk/libraries/rsl

Information about all Bodleian Libraries can be found here: https://www.bodleian.ox.ac.uk/libraries

The Mathematics Institute also has a small library of its own, the Whitehead Library. Students completing a dissertation may request a book for consultation if it is held only by the Whitehead Library (and not held by their College library, RSL or as an e-book), by emailing the Librarian at: libary@maths.ox.ac.uk . The book will be sent to the RSL where it can be consulted for reference (not borrowing).

Website: https://www.maths.ox.ac.uk/members/library

IT facilities

The IT services website details all the resources you can access for IT support, including digital skills tools, specialist software such as MatLab and Mathematica, as well as IT training.

https://www.it.ox.ac.uk/

Email

MSc students will receive a University 'single-sign-on' IT account. This will have an email address associated with it which will be of the format firstname.lastname@college.ox.ac.uk.

It is important that students either read this email regularly or set up a forward from it to an account which they do read regularly. MMathPhys students will retain the account they were issued with at the start of their degree. For further information about Departmental IT matters, including rules and regulations surrounding the use of IT facilities, please see http://www.maths.ox.ac.uk/members/it.

1.7 Glossary

The University of Oxford and its colleges have a unique collection of jargon, and nicknames for things, compiled over the centuries, some of which you may not have come across if you are a new student, or even if you've been here several years!

A non-exhaustive list has been compiled at this link: https://www.ox.ac.uk/about/organisation/history/oxford-glossary

Other useful terms include:

Bodcard: An informal name for your student identification card and University library card, issued once you have signed and returned your university contract and delivered to College.

Bop: A large college party usually run in the bar or similar location. Undergraduate bops generally admit students from the college in question. Graduate bops are usually much larger and involve many colleges.

Candidate Number: A number assigned to each student for the use of formal assessments and written examinations, which is usually available to students via student self-service after they have made their first exam entry. Candidate numbers are used instead of names to anonymise students during assessments. It is different from the student number.

Classes: Each Part C and MTP lecture course is accompanied by a set of classes (called 'intercollegiate classes' if they are held at Maths Institute and 'classes' if they are held in Physics.) For Maths courses, these will be run by a tutor and teaching assistant (TA), for Physics courses, these will be led by a TA, and will cover any problems that have arisen from the problem sheets.

Consultation Sessions: Revision sessions which take place for courses run by the Maths Institute in Weeks 2-5 of Trinity term.

Consultative Committee for Graduates (CCG): A committee consisting of postgraduate representatives from the Mathematical Institute and the departments two DGSs.

Course: This is the colloquial term both for the degree programme you are taking *and* individual courses, such as Kinetic Theory or C2.1 Lie Algebras, where these might be referred to as modules in other universities.

Examination Conventions: The Examination Conventions act as a supplement to the Examination Regulations. The Conventions explain how a student will be assessed for their course within the framework of the Examination Regulations.

Examination Schools: The building located on High Street where most in-person written examinations take place.

Formal Assessment: In the context of your degree, these are dissertations, mini-projects and take-Home Exams.

GSR: Graduate Supervision Reporting. Supervisors will submit termly reports through GSR on their student's academic progress.

JSC: Acronym for the Joint Supervisory Committee in Mathematical and Theoretical Physics, consisting of Maths and Physics academics who meet at least once a term to make decisions about the degree. Student representatives for the degree also attend these meetings

MCF: Masters in Mathematical and Computational Finance. A Master's course run by the Mathematical Institute.

MFoCS: Masters in Mathematics and Foundations of Computer Science. An MSc course run jointly by the Mathematical Institute and the Department of Computer Science.

MMSC: Masters in Mathematical Modelling and Scientific Computing. An MSc course run at the Mathematical Institute.

MPLS: Mathematical, Physical and Life Sciences Division.

MTP: The acronym for your degree, Mathematical and Theoretical Physics.

OMMS: Oxford Master's course in Mathematical Sciences.

Part C: The term given to the fourth-year undergraduate students studying for an integrated Masters. Part C is used to describe the courses that are open to these students.

PhysSoc: Oxford University Physics Society

Practicals: In the context of your degree, this means the homework options you choose. This is what they are called in Student Self Service, when you enter for exams.

Proctors: The two Proctors (Senior and Junior) are elected each year by colleges in rotation to serve for one year. The statutes provide that they shall generally ensure that the statutes, regulations, customs, and privileges of the University are observed. They serve on the University's main committees, and where not members of committees, may receive their papers and attend meetings but not vote. They have responsibilities under the statutes and regulations for aspects of student discipline, for ensuring the proper conduct of examinations and for dealing with complaints. They also carry out ceremonial duties, e.g. at degree ceremonies.

Student number: A number used to identify you as a student in day to day tasks, and can be used in conjunction with your name, unlike your candidate number.

Student Self Service: Student Self Service allows a student to access their student record and complete other tasks such as examination entry, and viewing examination results.

2. Course Overview and Structure

The course is offered in two modes: the MMathPhys for Oxford 4th year undergraduates, and the MSc for students from outside Oxford. **The academic content is identical for both modes.**

If you are an Oxford MPhys, MMath or MPhysPhil student who transfers to the MMathPhys, you will graduate as a “Master of Mathematical and Theoretical Physics” with a double classification consisting of the BA degree class in your original subject and an MMathPhys degree class. If you are a student on the MSc course, you will graduate with an “MSc in Mathematical and Theoretical Physics.”

These qualifications may be compared to national standards for higher education qualifications through the Framework for Higher Education Qualifications (FHEQ). The University Awards Framework (UAF) maps the awards of the University against the levels of the FHEQ. The FHEQ level for both the MMathPhys course and MSc course is 7. The relevant subject benchmark statements for the course, which set out expectations about standards of degrees in a given subject area, are Physics & Astronomy (QAA 2025) and Mathematics, Statistics & Operational Research (QAA 2023).

2.1 Aims

The Oxford Master's Course in Mathematical and Theoretical Physics aims to provide students with a high-level, internationally competitive training in mathematical and theoretical physics, right up to the level of modern research in the area.

As a graduate of this programme you will be in a prime position to compete for research degree places in an area of Theoretical and Mathematical Physics at leading research universities in the UK or overseas; or to pursue a research-related career, based on the acquired high-level ability in mathematics and its applications to physical systems, outside academia.

2.2 Learning Outcomes

During the course you will develop a knowledge and understanding of:

- Theoretical and Mathematical Physics, focusing on one of the areas of Theoretical Particle Physics, Theoretical Condensed Matter Physics, Theoretical Astrophysics/Fluids, or studying across these areas.
- A broad range of physical phenomena and their description within Theoretical and Mathematical Physics.
- A wide range of advanced mathematical techniques and structures and how they are applied in Theoretical Physics.

You will also have the opportunity to develop the following skills:

- Intellectual Skills
  - An appreciation of the principles of Theoretical and Mathematical Physics and their application to natural phenomena.
  - The ability to model physical phenomena and deploy a wide range of mathematical methods for their description.
  - A working knowledge of high-level mathematical methods and their application to systems in physics and beyond.
- Practical Skills
  - Ability to apply mathematical methods to practical problems.
  - Ability to construct, write-up and communicate logical arguments of some complexity.
- Transferable Skills
  - Ability to solve problems effectively and to apply high-level mathematical methods to a wide range of problems.
  - Ability to manage your time and to acquire a complex body of knowledge in a limited time.
  - Ability to manage your own learning and study for research or other professional qualifications.

2.3 Structure

The course requires that you 'offer', meaning that you choose to be assessed, in 10 units worth of courses.

The unit weighting of courses is decided by the course director and usually corresponds to the length of the lecture course. For example, a course with 16 hours of lectures will usually be worth 1 unit. A course with 24 hours of lectures, is worth 2 units.

In order to qualify for a Pass, students **must** offer:

- four units that are assessed by written invigilated exams
- a further three units that are assessed by written invigilated exams or by other formal assessments (dissertation or mini-project)
- three other units, which can be written invigilated exams, formal assessments or homework completion courses

It is your responsibility to ensure that you fulfil the requirements for the overall number of units and the number of assessed units. The modes of assessment and details on completion requirements for all courses are provided in the courses synopses of this handbook and Appendix A of the exam conventions.

There are no compulsory courses on this degree. So, you can tailor your choices to your personal interests.

Course synopses are available in Appendices A-C and on the MMathPhys website:
https://mmathphys.physics.ox.ac.uk/students

You are responsible for managing your course load

You should carefully consider how many courses you take each term and how many assessments you are prepared to undertake. Written examinations are sat in 0th week Hilary term, 0th week Trinity term and weeks 6-8 of Trinity term. Dissertations are also due in Week 6 of Trinity term. So it's especially important not to overburden yourself in Trinity term.

You will be offered academic guidance by your assigned Academic Adviser on choosing an individual path suitable for you. You may also reach out to the Course Director for advice. Course lecturers will also advise on the recommended background for their courses or possible follow-up courses you might wish to choose.

2.4 Approved Subjects

In addition to the courses listed in Appendices A-C students are allowed to choose a maximum of three units from other Maths Part C (https://courses.maths.ox.ac.uk/mod/folder/view.php?id=55865) or Physics Part C courses:

C1. Astrophysics C2. Laser Science and Quantum Information Processing C3. Condensed Matter Physics C4. Particle Physics C5. Physics of Atmospheres and Oceans C7. Biological Physics **C6. Theoretical Physics is not a permitted option.**

However, these must be approved by the Course Director.

Please do not email Prof Mason directly. A webform will be provided during 0th week and you should complete it by the end of week 1.

The Course Director will review your choices and the courses that you've selected from the curriculum to decide if your request is appropriate. **Approvals will be confirmed no later than Friday week 4.**

Please note, even if your request is approved, your place is dependent on there being room for you in the lectures and classes for the course. The MSc Course Administrator will liaise with the undergraduate team in Maths and the teaching administrator in Physics to ensure there is available space before confirming you can take this course.

3. Teaching and Learning

Teaching for the course will be provided jointly by the Department of Physics and the Mathematical Institute through lectures and classes.

You will be assigned an academic adviser from one or the other of these faculties, based on your areas of interest. Please note, this is separate to your college adviser.

Students undertaking a dissertation will have a separate dissertation supervisor with whom they will have supervision meetings.

Course timetables can be found on the MMathPhys website:

The Physics department hosts its course materials on Canvas:

There you will find lecture notes, recordings, reading lists and problem sheets for each course.

For courses taught by the Mathematical Institute, these are hosted on Moodle:

3.2 Lectures and Course Material

Lecture timetables can be found on the MMathPhys website:

Please note that with the number of courses offered on this course, there will inevitably be clashes on the timetable.

All lectures are recorded. So if you are not able to attend in person, you can watch these online (see following subchapter).

Course materials include lecture notes, recordings, reading lists and problem sheets recordings. Students will access these on two different platforms, depending on which department manages the course.

Physics

Canvas:

Maths

Moodle:

3.3 Classes

Enrolment

The majority of lecture courses will be accompanied by problem sets and weekly or fortnightly problem classes. These will be held in the same department that does the lecturing for the course.

Classes are not mandatory but it is in your own best interest to attend and complete the problem sheets, especially if you intend to offer the course as one of your assessed units. **Note that for Groups and Representations, you are assessed on both homework completion and the written invigilated exam.**

If you wish to be assessed by homework completion, then you **must** officially sign-up for the class and submit the required problem sheets.

If you wish to attend classes and receive feedback on submitted problem sheets, then you must officially sign-up to a class.

Dates and times of Physics classes can be found on Canvas:

To sign-up officially, you will need to log-in to the Teaching Management System (TMS) and enrol yourself for a class.

(Link)

Dates and times of Maths classes can be found on Moodle:

You also enrol in classes via Moodle.

Instructions can be found at the following link:

Class enrolment will be available by the end of 1st week each term and you will be notified by the MSc Course Administrator when it opens.

Please note, if you are taking the Advanced Philosophy of Physics option, you will arrange tutorials directly with the course tutor and there will not be a separate class registration process.

Withdrawal

You will have until Monday week 4 of each term to request a class switch or to withdraw from the class altogether. To do so, please contact your class tutor as well as the MTP administrator.

It is important to withdraw from a class if you no longer wish to take it. If you do not withdraw from a class, then your college will be charged for your attendance. Furthermore, when you withdraw from a class, your tutor and teaching assistant will know not to expect you to attend, and will not need to enquire any further to the reason for non-attendance or be concerned about your absence from classes.

If you have made an official exam entry for a course via student self-service (see page 14) and decide that you no longer wish to take that course, please note that in addition to withdrawing from the classes that accompany the lecture course and assessment, you must also withdraw from the assessment itself. Please contact your college office to officially withdraw from any exams, formal assessments or homework options for which you have made an official exam entry.

3.4 Dissertations

TBC

3.5 Advice on Teaching and Learning Matters

There are a number of people you can consult for advice on teaching and learning matters. Academic advisors will be appointed for all students at the start of the course and will be available for consultation on any academic matter. Students can also seek guidance on academic matters from their college personal tutor. All students will receive academic guidance from the Course Director.

If you have any issues with teaching or supervision please raise these as soon as possible so that they can be addressed promptly. Details of who to contact are provided in Section 7.2 Complaints and Appeals.

3.6 Skills and Learning Development

Expectations of Study

You are responsible for your own academic progress. Therefore, in addition to the formal teaching you receive through lectures, classes and dissertation tutorials, you will be expected to undertake a significant amount of self-directed independent study, both during term time and in the vacations. You are advised to read the University's guidance on undertaking paid work at http://www.ox.ac.uk/students/life/experience. You should seek advice from your advisor if you find it impossible to complete your academic work without spending significantly longer than 48 hours per week on a regular basis.

Your academic progress will be monitored by your academic advisor and also your college tutor. College tutors will receive reports from the class tutors for the classes you attend. In addition, academic advisors of MSc students will submit termly reports on their student's progress via the Graduate Supervision Recording (GSR). These reports are reviewed by the Course Director . If you are concerned about your academic progress, please contact your college tutor, academic advisor or the Course Director .

For MSc students, it is also mandatory to complete a self-assessment report via GSR for every reporting period. You can access GSR via the following link: https://www.ox.ac.uk/students/selfservice. Students will be sent a GSR automated email notification with details of how to log in at the start of each reporting window, and who to contact with queries. Completing the self-assessment will provide the opportunity to:

- Review and comment on your academic progress during the current reporting period

- Measure your progress against the timetable and requirements of your programme of study
- Identify skills developed and training undertaken or required
- List your engagement with the academic community
- Raise concerns or issues regarding your academic progress to your Academic Advisor
- Outline your plans for the next term (where applicable)

If you have any difficulty completing this you must speak to your Academic Advisor or the Course Director. Your self-assessment report will be used by your Academic Advisor as a basis to complete a report on your performance this reporting period, for identifying areas where further work may be required, and for reviewing your progress against agreed timetables and plans for the term ahead. GSR will alert you by email when your Academic Advisor has completed your report and it is available for you to view.

3.6 University Lectures and Departmental Seminars

University lectures in all subjects are open to all students. A consolidated lecture list is available on the University website at: http://www.ox.ac.uk/students/academic/lectures/.

Seminars and colloquia given in the Mathematical Institute and Physics Department, often by mathematicians and physicists of international repute, are announced on the departmental notice boards: https://www.maths.ox.ac.uk/events/list and https://www.physics.ox.ac.uk/seminars-and-colloquia. You are encouraged to attend any which interest you.

Particle Theory seminars are listed here and here.

3.7 Study Skills

Much of the advice and training in study skills will come in the regular class teaching you receive. A wide range of information and training materials are available to help you develop your academic skills – including time management, research and library skills, referencing, revision skill and academic writing – through the Oxford Student website: https://www.ox.ac.uk/students/academic/guidance/skills.

3.8 Key Teaching Links

Lecture Timetable: http://mmathphys.physics.ox.ac.uk/course-schedule

https://www.maths.ox.ac.uk/members/students/lecture-lists

Maths Class Lists: https://courses.maths.ox.ac.uk/course/index.php?categoryid=857

Physics Class Information: Follow links to course pages from https://mmathphys.physics.ox.ac.uk/course-schedule

And on Canvas: https://canvas.ox.ac.uk/courses/276069

Problem Sheet Submission: https://courses.maths.ox.ac.uk/course/index.php?categoryid=857 (Maths) and https://canvas.ox.ac.uk/courses/226235/assignments (Physics)

3.1 Lectures and Course Materials

Lecture timetables can be found on the MMathPhys website: https://mmathphys.physics.ox.ac.uk/course-schedule

Please note that with the number of courses offered on this course, there will inevitably be clashes on the timetable.

All lectures are recorded. So if you are not able to attend in person, you can watch these online at the associated platform below.

Course materials including lecture notes, recordings, reading lists and problem sheets are available on one of the two platforms listed below, depending on which department manages the course. You will submit problem sheets and receive feedback on them at the same platforms.

Physics: https://canvas.ox.ac.uk/courses/294961

The Physics department uses Canvas. Guides to Canvas can be found here: https://www.ox.ac.uk/students/academic/guidance/canvas

Maths: https://courses.maths.ox.ac.uk/course/index.php?categoryid=931

The Mathematical Institute uses Moodle. Guides to Moodle can be found here: https://www.maths.ox.ac.uk/members/it/faqs/moodle-courses-system/students

3.2 Classes

The majority of lecture courses are accompanied by problem sets and weekly or fortnightly problem classes. These will be held in the same department that does the lecturing for the course.

Classes are not mandatory but it is in your own best interest to attend and complete the problem sheets, especially if you intend to offer the course as one of your assessed units. **Note that for Groups and Representations, you are assessed on both homework completion and the written invigilated exam.**

If you wish to attend classes and receive feedback on submitted problem sheets, then you **must** officially sign-up to a class.

If you wish to be assessed by homework completion, then you **must** officially sign-up for the class and submit the required problem sheets.

Enrolment

Note: This is not the same as enrolling for the exam – you must enrol for your exams in a separate process (see Chapter 4).

Physics Classes

Dates and times of Physics classes will be published on Canvas wherever possible, though not all lecturers choose to set up webpages. In which case, they will be on TMS (see below).

To sign-up officially for any Physics classes, you will need to log-in to the Teaching Management System (TMS) and enrol yourself for a class: https://tms.ox.ac.uk/

Log-in with your SSO. You will then see a list of the courses that you are eligible to register for. Clicking into these courses will provide you with a list of groups and class times which you can sign up for.

Maths Classes

Dates and times of Maths classes can be found on Moodle. You also enrol in classes via Moodle.

Instructions can be found at the following link: https://www.maths.ox.ac.uk/members/it/faqs/moodle-courses-system/students/course-enrolment

Class enrolment will be available by the end of 1st week each term and you will be notified by the MSc Course Administrator when it opens.

Please note, if you are taking the Advanced Philosophy of Physics option, you will arrange tutorials directly with the course tutor and there will not be a separate class registration process.

Withdrawal

Note: This is not the same as withdrawing from an examination or other assessment. To do that, you need to contact your college's academic office.

You will have until Monday week 4 of each term to request a class switch or to withdraw from the class altogether. To do so, please contact your class tutor as well as the MSc Course Administrator.

It is important to withdraw from a class if you no longer wish to take it. **If you do not withdraw from a class, then your college will be charged for your attendance.** Furthermore, when you withdraw from a class, your tutor and teaching assistant will know not to expect you, and will not need to enquire any further or be concerned about your absence from classes.

3.3 Expectations of Study

You are responsible for your own academic progress. Therefore, in addition to the formal teaching you receive through lectures, classes and dissertation tutorials, you will be expected to undertake a significant amount of self-directed independent study, both during term time and in the vacations.

You should seek advice from your advisor if you find it impossible to complete your academic work without spending significantly longer than 48 hours per week on a regular basis.

There are a number of resources available to help develop your study skills:
https://www.ox.ac.uk/students/academic/guidance/skills

and especially at master's level: https://www.ox.ac.uk/students/academic/guidance/skills/postgrad-taught-skills

3.4 Academic Advsiors and Reporting

Your college will assign you a tutor and the Maths and Physics departments will choose an academic advisor for you.

Advisors should be the first point of contact for students on all academic matters and are expected to monitor their student's progress throughout the year.

Advisors and students are expected to meet a minimum of two times in Michaelmas Term: once at the beginning of term and once at the end. In Hilary Term and Trinity Term, students will meet with their supervisors a minimum of once per term.

Advisors should make initial contact with their advisees to arrange further contact. After the initial meeting between student and advisor, **the onus will be on the student to arrange further meetings.**

Your academic progress will be monitored by your academic advisor and also your college tutor. College tutors will receive reports from the class tutors for the classes you attend. In addition, academic advisors of MSc students will submit termly reports on their student's progress via the Graduate Supervision Recording (GSR). These reports are reviewed by the Course Director.

For MSc students, it is mandatory to complete a self-assessment report via GSR for every reporting period. You can access GSR via the following link: https://www.ox.ac.uk/students/selfservice. Students will be sent a GSR automated email notification with details of how to log in at the start of each reporting window, and who to contact with queries.

- Completing the self-assessment will provide the opportunity to:
  Review and comment on your academic progress during the current reporting period
- Measure your progress against the timetable and requirements of your programme of study
- Identify skills developed and training undertaken or required
- List your engagement with the academic community
- Raise concerns or issues regarding your academic progress to your Academic Advisor
- Outline your plans for the next term (where applicable)

If you have any difficulty completing this you must speak to your Academic Advisor or the Course Director. Your self assessment report will be used by your Academic Advisor as a basis to complete a report on your performance this reporting period, for identifying areas where further work may be required, and for reviewing your progress against agreed timetables and plans for the term ahead. GSR will alert you by email when your Academic Advisor has completed your report and it is available for you to view.

3.5 Working while Studying

The master's is a demanding course and it is not advised to take-up paid work during your studies. For international students on student visas there is a strict 20hr per week limit on paid work in term time. Please view the following University guidance for more information: https://academic.admin.ox.ac.uk/policies/paid-work-guidelines-graduate-students

Information on work experience, internship opportunities and careers services is available here: http://www.ox.ac.uk/students/life/experience.

3.6 Further Learning Opportunities

University lectures in all subjects are open to all students. A consolidated lecture list is available on the University website at: http://www.ox.ac.uk/students/academic/lectures/

Seminars and colloquia given in the Mathematical Institute and Physics Department, often by mathematicians and physicists of international repute, are announced on the departmental notice boards:

https://www.maths.ox.ac.uk/events/list

https://www.physics.ox.ac.uk/seminars-and-colloquia.

You are encouraged to attend any which interest you.

4. Examinations and Assessments

All of the units you undertake will have either a component of formal assessment (written invigilated exam, take-home exam, mini-project or dissertation) or a homework completion option/requirement. Each unit will be assessed by the method most suited to the material being taught.

Both the course synopses and the examination conventions show which courses are assessed, by which method, and which courses have a homework completion option/requirement.

For revision purposes, past papers for invigilated written examiniations, take-home exams and mini-projects can be found here: https://mmathphys.physics.ox.ac.uk/past-examination-papers

Exam Conventions

The examination conventions for the course are the formal record of the specific assessment standards for the course. They set out how each unit will be assessed and how the final degree classification will be derived from the marks obtained for the individual units. They include information on marking scales, marking and classification criteria, scaling of marks, formative feedback, re-sits, and penalties for late submission.

This is the most important course document for you to familiarise yourself with. Please make sure to read it thoroughly and refer back to it whenever you have a query regarding exams and assessment. **However, if there is a conflict between the information in the exam conventions and the University-wide Examination Regulations then you should follow the Examinations Regulations.**

The examination conventions for 2025-26 can be found on the course website at http://mmathphys.physics. ox.ac.uk/.

University-wide Examination Regulations: https://examregs.admin.ox.ac.uk/

Examiners' Reports

Past examiner's reports can be found here: http://mmathphys.physics.ox.ac.uk/students

Prizes

A prize may be awarded by the Examiners for excellence in examination for the Master of Mathematics and Physics (MMathPhys) or MSc in Mathematical and Theoretical Physics. The assessors of a dissertation that, in their view, shows particular originality and/or insight may recommend to the Examiners that this dissertation be given a commendation. A prize may be awarded by the examiners for the best dissertation.

4.1 Exam Entry

You will need to formally enter for the units you wish to be assessed on, including those courses which only have a homework completion requirement, by completing an examination entry form. This is done online through Student Self Service (https://evision.ox.ac.uk/) and further information on the process can be found at https://www.ox.ac.uk/students/academic/exams/examination-entry

For this course there will be three examination entry dates:

Exam Entry Period	Assessments	Example
30th October - 6th November 2025	0th week Hilary invigilated written examinations ALL APPROVED SUBJECTS	Quantum Field Theory exam C3 Condensed Matter Physics
22nd - 29th January 2026	0th week and 6th-8th week Trinity invigilated written examinations Michaelmas Term practicals (homework) Hilary term submissions (such as mini-projects released in Hilary Term)	Cosmology exam; Algebraic Geometry exam Anyons and Topological Phases of Matter homework Galactic and Planetary Dynamics mini-project
7th -14th May 2026	Hilary term practicals (homework) Trinity term practicals (homework) Trinity term submissions (such as the dissertation)	Advanced Fluid Dynamics homework Astroparticle Physics homework Dissertation (1 unit); Dissertation (2 units)

When completing your examination entry, you should try to ensure that the decisions you make are as final as possible. Please note that you must take care in selecting the correct options; it is your responsibility to ensure you are entered for the courses you intend, and it is not always possible to make amendments to your entries once you have submitted the form. In particular, please keep the below terminology in mind when completing your entries, as it is not always possible to rectify mistakes

Exam	Papers assessed by written in-person examination
Submission	Work assessed by written submissions; this includes dissertations, mini-projects, and papers assessed by take-home exam. This does not include homework completion.
Practical	This only denotes homework completion courses; you should always select this where you wish to be assessed on homework completion rather than any alternative assessment method for the course.

If you wish to withdraw from an assessment after the exam entry window has closed, you can request a withdrawal from your college up to a week before the exam/assessment deadline takes place. For homework completion courses, you must withdraw before the final homework deadline. If a course requires both homework completion and an examination, you will not be able to withdraw from the examination once the final homework completion deadline has passed.

Please discuss with your college tutor or academic advisor before making the decision to withdraw. **There is no fee for withdrawal.**

If you with to add an additional assessment after the exam entry window has closed, you will need to make a 'Change of Option' request to your college and **pay a late entry fee.** You should do this at least ten days before the assessment, so that the Academic Records Office has time to process the request.

4.2 Invigilated Written Examinations

Written invigilated exams take place in the Examiniation Schools in 0th week Hilary, 0th week Trinity. Part C (4th year undergraduate) exams, and papers that share material with Part C exams take place between 6-8th week Trinity.

The examination timetable for invigilated written examinations will be set by the Examination Schools and published a month prior to the exam period at: http://www.ox.ac.uk/students/academic/exams/timetables.

Candidates are required to wear sub fusc to written inviligated exams, unless they have a specific exam adjustment in place to excuse it.

A guide to sub fusc requirements can be found here: https://www.ox.ac.uk/students/academic/dress

Further information on required conduct for in-person examiniations is available here: https://www.ox.ac.uk/students/academic/exams/completing-an-exam/in-person-exams

Please make sure to read it thoroughly.

4.2.1 Exam Adjustments

Students may be entitled to exam adjustments such as taking in-person examiniations in college, having extra time, wearing noise cancelling headphones etc.

To apply for exam adjustments, you will need to contact your college office or disability advisor, who can advise on reasonable adjustments and what information you will need to provide to support an application for those adjustments to be considered. **You must do this is as soon as possible after matriculation and before Friday of week 4 the term before your exams.**

Then, contact the Disability Advisory Service (DAS) to assess your requirements. They can provide a Student Support Plan, which may be used in evidence for an application for adjustments.

Provide evidence to your college office to support your request. Then your college office will submit an application for consideration on your behalf.

Approved adjustments will be notified to your college office and your course organiser/s. Your approved adjustments will be visible to you in self service and your individual exam timetable (when this is published). Any issues should be raised with your college office as soon as possible.

For more information, see here: https://www.ox.ac.uk/students/academic/exams/examination-adjustments

You can also apply for adjustments/alternative arrangements on the grounds of religious observance, for example if an exam is likely to take place during Ramadan or a religious holiday on which you are not allowed to work. You should apply for this through your college office, ideally before week 6 of Michaelmas term. Further gudiance is also available at: https://www.ox.ac.uk/students/academic/exams/examination-adjustments

4.2.2 If you cannot attend your exam

If you can't attend an exam due to 'illness or other urgent cause that is unforeseeable, unavoidable and/or insurmountable' you should ask your college to apply to the Proctor's for you to be excused, meaning that your absence does not impact your overall marks and degree classification at the end of the year. Your college can apply **up to 4 weeks before the date of the exam and within 14 days after.**

For more information, see here: https://www.ox.ac.uk/students/academic/exams/problems-completing-your-assessment

4.4 Mini-projects and take-home exams

Some units will be assessed wholly or partially by submitted work. This will take one of two forms: mini-project or take-home examination. The deadline for the submission of the assessment for each unit is given in the table included in the examination conventions.

These should be submitted through Inspera. Instructions for using Inspera can be found at: https://www.ox.ac.uk/students/academic/exams/submission

The examiners will send out notices to candidates detailing where your work should be submitted and what format your submission should be in (e.g. handwritten or word-processed). Candidates will be required to submit an electronic copy and instructions on the online submission process will be included in the notice to candidates.

It is vital that you submit your work by the given deadline as any late submission will be reported to the Proctors and a late submission penalty may be applied. Please see the examination conventions and the following webpage (https://www.ox.ac.uk/students/academic/exams/problems-completing-your-assessment) for advice on what to do if you are unable to submit your work on time due to medical emergency or other urgent cause.

4.5 Dissertations

You may offer a dissertation for one or two units.

For a one-unit dissertation, you are expected to spend the equivalent time and effort on your dissertation as a 16-hour lecture course, including the associated private study, completion of problem sheets, and dedicated revision for examinations. For a two-unit dissertation, you are expected to spend the equivalent time and effort on your dissertation as a 32-hour lecture course, with the same considerations for associated work.

Please note, that if you choose to do a single-unit dissertation, **you will be required to give an informal presentation to your supervisor and at least one other person as part of your supervision.**

Topics are available from Appendix E of this handbook. Please note, this list is not considered final until after the first meeting of the Joint Supervisory Committee for MMathPhys/MSc Mathematical and Theoretical Physics, around week 3 of Michaelmas term.

You can also propose a topic of your own, in which case you must find an appopriate faculty member or research staff to supervise. You must make an intitial proposal to them and they will approve or help you make changes to the proposal where necessary. If they are unable to supervise you or feel your wrok is more suited to another member of staff, they may suggest someone else.

All students wishing to take a dissertation must formally apply through the following link on the Maths website (make sure you are signed in with your SSO): https://www.maths.ox.ac.uk/form/webform-16642

The form will be open between week 4 - 6. The deadline to apply is **Monday of Week 6 in Michaelmas term.**

More specific guidance is available on the course website: http://mmathphys.physics.ox.ac.uk/students

The deadline for submission of the dissertation is 12 noon on Monday of week 6, Trinity term. Dissertations must be submitted electronically and instructions on the online submission process will be included in the notice to candidates.

4.6 Extensions

If you are not able to submit a mini-project or your dissertation by the required deadline then you can request an extension.

You can request **two 7-day extensions** over the course of the academic year by self-certification through Student Self-Service. These do not require any approval and will be granted automatically. You may not request two 7-day extensions for the same submission, that is, you cannot have a 14 day extension by self-certification.

You can request these up to 2 weeks in advance of the deadline or 24 hours after the deadline.

For any more extensions, or for an extension longer than 7 days, your college must make the request for you and these will be granted by the Proctors' Office.

See here for more details: https://www.ox.ac.uk/students/academic/exams/problems-completing-your-assessment

The maximum extension that can be granted for any piece of work is 12 weeks. **If you are granted an extension of a month or longer for a piece of work in Trinity term, you should not book your graduation ceremony until you have recieved your results. Otherwise, you may have to cancel your booking if the Examiners are delayed in confirming your results.**

If you submit an assessment after the deadline and do not have an extension, then marks will be deducted from your asssessment. Please refer to the Examination Conventions to see how many marks are deducted per hour overdue.

If you were unable to submit on time due to 'illness or other urgent cause that was unforeseeable, unavoidable and insurmountable', you can contact your college to apply to have the late penalty removed. Your college must apply to the Proctors within 14 days of your deadline. It is not guaranteed that the Proctors will agree to remove the penalty.

4.7 Homework completion

For course with a homework completion option or requirement, the lecturer of the course will assign problem sheets to be completed. There may be between one to four problem sheets, depending on how the lecturer's choice.

Each submission will be marked by a teaching assistant (TA) based on solutions provided by the lecturer. Problem sheets will be marked using a letter system A/B/C for problems solved or attempted competently (A for excellent, B good, C fair), and F for those problems which are not handed in or, if attempted, show insufficient understanding of the concepts taught in the lectures. The TA will record the mark of each problem and return the marked scripts as promptly as possible.

The homework requirement for a course will have been completed if **50% of each problem sheet** assigned has a mark A/B/C. Otherwise the homework requirement will normally be judged to have not been completed. The Examiners will make the final determination as to whether or not each student has completed the homework requirement for any given unit. **If you fail to submit any of the problem sheets for the course, you will fail,** unless you have been granted an eextension or excusal (see below).

Some of the courses will be accompanied by classes led by tutors in order to discuss the homework assignments. Please note, due to the short eight week teaching structure at Oxford, the teaching and homework schedules may not always align perfectly. Lecturers may sometimes assign problem sheets on topics that have not yet been covered in lectures. Students are expected to engage in self-study, referring to the lecture notes that are provided in advance and other reading material available.

Late homework submission

Each homework will have a submission deadline after which submissions will not be accepted and an F will be automatically given.

If you cannot submit your homework on time due to acute illness or other urgent cause (see Annex J of the Examinations and Asessments Framework, Points 14-25, for the definition of 'urgent cause') students should submit a formal request for an extension or excusal for that homework using this form: https://forms.office.com/e/Ka8efNgANC.

DO NOT informally request an extension from your tutor, TA or lecturer. Nor may you contact the Course Administrator, Course Director or any of the Examiners for this.

Do not request an extension via Student Self-Service either. The only way to request an extension is through the form linked above.

Where the extended deadline requested falls before the class at which the work will be discussed, the request will be considered by the lecturer of the course; where the extended deadline would fall after the class, or where an excusal is requested, the request will be considered by the Chair of Examiners.

4.8 Mitigating Circumstances

If you suffer from an acute illness or other personal circumstances that you believe has affected your performance in an asessment (either during an exam, or in the revision period before, or while writing up a submission), you can submit a mitigating circumstances notice to your examiners (MCE) to let them know. The Examiners will consider whether the outcome for affected papers or overall classification should be adjusted.

You can submit an MCE via Student Self-Service. However, you are encouraged to contact your college first, so that they can advise you on how to gather evidence.

Please see student guide here:
https://www.ox.ac.uk/sites/files/oxford/Mitigating%20Circumstances%20Notices%20%E2%80%93%20Student%20Guidance.docx

You are encouraged to submit an MCE as soon as possible after completing the affected assessment. You can submit an MCE at any time after the asessment is completed however, it must be submitted no later than noon the day before the final exam board meeting (mid-July, exact date to follow), or it will not be considered by the Examiners.

You may submit an MCE after that point, no more than a month after the final exam board meeting, but you must provide a reason for why you did not submit before. The Proctor's Office will review the cases and they will decide if the MCE should be forwarded to the Examiners at that point. So if you submit an MCE after the exam board, it is not guaranteed that the Examiners will review it.

Please note, if you are struggling with your studies for any reason, please contact your academic advisor and your college's welfare team for support. Don't wait until the last moment and only apply for an MCE. Your college is there to support you and you are more likely to succeed in your studies if you reach out for help when you need it.

4.9 Plagiarism

Presenting work or ideas from another source as your own, with or without consent of the original author, by incorporating it into your work without full acknowledgement constitutes plagiarism. All published and unpublished material, whether in manuscript, printed or electronic form, is covered under this definition, as is the use of material generated wholly or in part through use of artificial intelligence (save when use of AI for assessment has received prior authorisation e.g. as a reasonable adjustment for a student's disability). Plagiarism can also include re-using your own work without citation. Under the regulations for examinations, intentional or reckless plagiarism is a disciplinary offence.

Please see the University's guidance on plagiarism:

http://www.ox.ac.uk/students/academic/guidance/skills/plagiarism

5. Services

The Oxford students' website will provide most of the information you need on what services are available to you through the university. https://www.ox.ac.uk/students

Please refer to your college website and handbook for college specific services.

More detail is provided in the following subchapters.

University Policies

The University has a wide range of policies and regulations that apply to students. These are easily accessible through the A–Z of University regulations, codes of conduct and policies available at http://www.ox.ac.uk/students/academic/regulations/a-z. Particular attention is drawn to the following University policies.

Equal Opportunities Statement: https://edu.admin.ox.ac.uk/equality-policy

Intellectual Property Rights: https://www.ox.ac.uk/students/academic/guidance/intellectual-property

Code on Harassment: https://edu.admin.ox.ac.uk/harassment-advice

Policy on Plagiarism: http://www.ox.ac.uk/students/academic/guidance/skills/plagiarism

5.1 Who is Responsible

Different parts of the university are resonsible for providing different support services and administrative support. Here is a brief summary of who to go to for what issue.

Issues with Moodle, Canvas, TMS - Course Administrator (mmathphys@maths.ox.ac.uk)

General course information and administrative queries - Course Administrator (mmathphys@maths.ox.ac.uk)

Academic advice - Academic advisor or Course Director (lionel.mason@maths.ox.ac.uk)

Mitigating Circumstances - College

Extensions - College

Excusals and late penalty waivers - College

Exam entry change - College

Suspending your studies/return from suspension - Course Administrator (mmathphys@maths.ox.ac.uk)

Welfare - College welfare support. There is also the university counselling service: https://www.ox.ac.uk/students/welfare/counselling; counselling@admin.ox.ac.uk

Diasbility support -

University's Disability Advisory Service: http://www.ox.ac.uk/students/welfare/disability

Disability Coordinator (Mathematics): Charlotte Turner-Smith (academic.administrator@maths.ox.ac.uk)

Disability Coordinator (Physics): Carrie Leonard-McIntyre (c.leonard-mcintyre@physics.ox.ac.uk)

Every college has their own systems of support for students, please refer to your college handbook or website for more information on who to contact and what support is available through your college.

Details of the wide range of sources of support available more widely in the University are available from the Oxford Student website (http://www.ox.ac.uk/students/welfare), including in relation to mental and physical health and disability.

5.2 Student Representation and Feedback

Joint Supervisory Commitee

Students will be able to nominate two representatives (one MSc MTP student, one MMathPhys student) to sit on the Joint Supervisory Committee (JSC) which oversees the course. Volunteers will be sought at the Induction Session and an election held if necessary. The student representatives will be able to raise matters with the JSC on behalf of the cohort.

Consultative Committee for Graduates – Mathematics

The Consultative Committee for Graduates meets regularly once a term and discusses any matters that graduate students wish to raise. Students will be invited to nominate a representative to serve as an MSc rep on this committee via email in Michaelmas term.

The Physics Joint Consultative Committee

The Physics Joint Consultative Committee (PJCC) has elected undergraduate members who meet twice in MT and HT, and once in TT to discuss both academic and administrative matters with academic staff representatives. See https://pjcc.physics.ox.ac.uk/ for more information.

Divisional and University Representatives

The MPLS Division also runs a divisional Undergraduate Joint Consultative Forum, a divisional Graduate Joint Consultative Forum, and is establishing a Joint Consultative Forum for Graduate Taught Courses. Each Forum is chaired by the senior MPLS Academic who is responsible for that area across the Division, an undergraduate or graduate representative from each department, the undergraduate or graduate representative on the Academic Committee and Divisional Board, and the Oxford Student Union (Vice-President (Access and Academic Affairs) or Vice-President (Graduates).

Student representative sitting on the MPLS Divisional Board are selected through a process organised by Oxford SU. Details can be found on the Oxford SU website along with information about student representation at the University level.

Opportunities to Provide Feedback

Students will be asked to complete questionnaires evaluating the teaching received for each unit. Please take time to complete these as your feedback is valuable for future course planning.

MSc students, like all students on matriculated courses, will be surveyed on all aspects of their course (learning, living, pastoral support, college) through the annual PTES (Postgraduate Taught Experience Survey). Previous results can be viewed by students, staff and the general public at: https://www.ox.ac.uk/students/life/student-surveys. MMathPhys students, as final year undergraduates, will be surveyed through the National Student Survey instead. Results from previous NSS can be found at https://www.thestudentsurvey.com/.

Key Student Representation Links

CCG: http://www.maths.ox.ac.uk/members/students/postgraduate-courses/doctor-philosophy/ consultative-committee-graduates. (Minutes of meetings and list of student representatives.)

Oxford SU: http://oxfordsu.org/

University Surveys: https://www.ox.ac.uk/students/life/student-surveys

5.3 Complaints and Appeals

The University, the Mathematical, Physical and Life Sciences Division, the Department of Physics and the Mathematical Institute all hope that provision made for students at all stages of their course of study will result in no need for complaints (about that provision) or appeals (against the outcomes of any form of assessment).

Where such a need arises, an informal discussion with the person immediately responsible for the issue that you wish to complain about (and who may not be one of the individuals identified below) is often the simplest way to achieve a satisfactory resolution.

Many sources of advice are available from colleges, faculties/departments and bodies like the Counselling Service or the OUSU Student Advice Service, which have extensive experience in advising students. You may wish to take advice from one of those sources before pursuing your complaint.

General areas of concern about provision affecting students as a whole should be raised through Joint Consultative Committees or via student representation on the faculty/department's committees.

Complaints

If your concern or complaint relates to teaching or other provision made by the faculty/department, then you should raise it with Director of Undergraduate Studies (Dr Richard Earl (Maths), Prof Jonathan Jones (Physics)) or with the Director of Graduate Studies (Prof Christoph Reisinger (Maths) as appropriate. If your concern relates to the course as a whole, rather than to teaching or other provision made by one of the faculties/departments, you should raise it with Prof Caroline Terquem, Chair of the Joint Supervisory Committee for the Master of Mathematical and Theoretical Physics/MSc in Mathematical and Theoretical Physics. Complaints about departmental facilities should be made to the Head of Administration/Head of Physical Resources (Dr Jocasta Gardner (Maths), Mr. Simon Probert (Physics)). If you feel unable to approach one of those individuals, you may contact the Head of Department Prof James Sparks (Maths), The officer concerned will attempt to resolve your concern/complaint informally.

If you are dissatisfied with the outcome, you may take your concern further by making a formal complaint to the Proctors under the University Student Complaints Procedure https://www.ox.ac.uk/students/ academic/complaints.

If your concern or complaint relates to teaching or other provision made by your college, you should raise it either with your tutor or with one of the college officers, Senior Tutor, Tutor for Graduates (as appropriate). Your college will also be able to explain how to take your complaint further if you are dissatisfied with the outcome of its consideration.

Academic Appeals

An academic appeal is an appeal against the decision of an academic body (e.g. boards of examiners, transfer and confirmation decisions etc.), on grounds such as procedural error or evidence of bias. There is no right of appeal against academic judgement. If you have any concerns about your assessment process or outcome it is advisable to discuss these first informally with your subject or college tutor, Senior Tutor, course director, director of studies, supervisor or college or departmental administrator as appropriate. They will be able to explain the assessment process that was undertaken and may be able to address your concerns. Queries must not be raised directly with the examiners. If you still have concerns you can make a formal appeal to the Proctors who will consider appeals under the University Academic Appeals Procedure (https://www.ox.ac.uk/students/academic/complaints).

5.4 Careers Service

Careers guidance is provided by the Careers Service (http://www.careers.ox.ac.uk/), which also provides training in writing applications, interview techniques and analysis of transferable skills. The Careers Service provides information about occupations and employers, and advertises work experience opportunities.

In addition to its general programme, the Careers Service runs an annual ‘Jobs for Mathematicians’ half-day, in collaboration with the Mathematical Institute. At this event there are talks from alumni working in various industries and a talk for those interesting in continuing on to further postgraduate study. Further information about postgraduate study opportunities at the Mathematical Institute and Physics respectively can be found here:

https://www.maths.ox.ac.uk/study-here/postgraduate
study

https://www.physics.ox.ac.uk/study/postgraduates

5.5 Volunteering Opportunities

Maths Outreach

The Department has an active Outreach programme https://www.maths.ox.ac.uk/outreach which runs throughout the year, with events and programmes for school students aged 5-18. You can take a look at what's currently happening on the website. Keep an eye out throughout the year for e-mails asking for volunteers for various events and other ways to get involved. Contact outreach@maths.ox.ac.uk if you would like to get involved.

Physics Outreach

The Physics department similarly has an outreach programme with events for primary and secondary schools. See https://www.physics.ox.ac.uk/engage/schools for more information and email engage@physics.ox.ac.uk if you would like to get involved.

5.6 Societies

There are number of Mathematics and Physics student societies which you may like to join. Details of the main societies are given below. In addition, there are also over 200 clubs and societies covering a wide range of interest which you may join or attend. A full list is available at http://www.ox.ac.uk/students/life/ clubs/list.

Invariants

The Oxford University's student society for Mathematics. The society promotes Maths and hosts informal lectures, often given by leading mathematicians. Website: http://www.invariants.org.uk/.

LGBTI∧3

LGBTI∧3 is the student group for all LGBTQ+ identifying students in Maths, Stats and Computer Science.
Contact: oxlgbtqubed@gmail.com.

Mirzakhani Society

The Mirzakhani Society is a society aimed at supporting women and non-binary students in Oxford who are studying maths.
Contact: mirzakhanisociety@gmail.com.

The Oxford University Physics Society

The Oxford University Physics Society (PhysSoc) is a student society that exists to promote and encourage an interest in Physics in and around Oxford University. PhysSoc hosts talks most weeks during term time in the Physics Department, often by leading experts and also holds social events which are a great opportunity to get to know others with an interest in all things Physics. Website: https://oxfordphyssoc.wordpress.com/

Appendices

- Appendix 1 - Course Curriculum
- Appendix 2 - Specialized Pathways
- Appendix 3 - Dissertation Proposals

A - Michaelmas Courses

Advanced Philosophy of Physics

Department: Philosophy

Lecturers: Prof Adam Caulton, Prof James Read, Prof Christopher Timpson

Course Weight: 1.5 units/24 lectures (continues in Hilary)

Assessment Method: mini-project or homework completion

Course Synopsis: This series of classes will cover contemporary topics in the philosophy of physics, with emphasis on: thermal physics (thermodynamics and statistical mechanics), the role of symmetries in physical theories, spacetime (especially the general theory of relativity), and advanced topics in the philosophy of quantum theory (which may include the role of decoherence in solving the measurement problem, the interpretation of probability, and topics in quantum field theory). Those MMathPhys and MSc students taking the course in the mini-project or homework mode also receive 8 hours of tutorials (usually as one of a pair) from one of the external lecturers. These tutorials are usually spread throughout the year, with the first 4 in Michaelmas Term. Students are expected to produce an essay of between 2,000-2,500 words for each tutorial. For those taking the course in mini-project mode, two of these tutorials will be given over to discussing drafts of the two 5,000-word essays submitted by each candidate for assessment in week 4 of Trinity Term.

Anyons and Topological Quantum Field Theory

Department: Physics

Lecturer: Prof Steve Simon

Course Weight: 1 unit/ 16 lectures

Assessment Method: written exam in HT week 0 or homework completion

Course Synopsis: The intersection of topology and quantum mechanics is an enormous and still growing field. It touches upon physics topics ranging from quantum gravity to quantum information to materials physics and condensed matter experiment, as well as being one of the most interesting directions in the mathematical study of topology. This is the backdrop upon which we build. A number experiments from the last few years have finally detected and measured anyons — particles that are neither bosons nor fermions – in condensed matter systems (GaAs quantum wells, graphene) as also as in rudimentary quantum computers (superconducting qubits, trapped ion qubits, rydberg atoms). The presence of anyons tells us that our systems are necessarily nontrivial topological quantum field theories! This makes the topic particularly exciting right now!

For a full lecture syllabus, see here: 2024 Anyons Lecture Syllabus

C3.1 Algebraic Topology

Department: Maths

Lecturer: Prof Andras Juhasz

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: A3 Rings and Modules is essential, in particular a solid understanding of groups, rings, fields, modules, homomorphisms of modules, kernels and cokernels, and classification of finitely generated abelian groups.
A5 Topology is essential, in particular a solid understanding of topological spaces, connectedness, compactness, and classification of compact surfaces. B3.5 Topology and Groups is helpful but not necessary, in particular the notion of homotopic maps, homotopy equivalences, and fundamental groups will be recalled during the course. There will be little mention of homotopy theory in this course as the focus will be instead on homology and cohomology.

Course Synopsis: Homology theory is a subject that pervades much of modern mathematics. Its basic ideas are used in nearly every branch, pure and applied. In this course, the homology groups of topological spaces are studied. These powerful invariants have many attractive applications. For example we will prove that the dimension of a vector space is a topological invariant and the fact that 'a hairy ball cannot be combed'.

C3.3 Differentiable Manifolds

Department: Maths

Lecturer: Prof Dominic Joyce

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: A5: Topology and ASO: Introduction to Manifolds are strongly recommended. (Notions of Hausdorff, open covers, smooth functions on R^n will be used without further explanation.) Useful but not essential: B3.2 Geometry of Surfaces.

Course Synopsis: A manifold is a space such that small pieces of it look like small pieces of Euclidean space. Thus a smooth surface, the topic of the Geometry of Surfaces course, is an example of a (2-dimensional) manifold.
Manifolds are the natural setting for parts of classical applied mathematics such as mechanics, as well as general relativity. They are also central to areas of pure mathematics such as topology and certain aspects of analysis.

In this course we introduce the tools needed to do analysis on manifolds. We prove a very general form of Stokes' Theorem which includes as special cases the classical theorems of Gauss, Green and Stokes. We also introduce the theory of de Rham cohomology, which is central to many arguments in topology.

C3.4 Algebraic Geometry

Lecturer: Prof Damian Rossler

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: A3 Rings and Modules and B2.2 Commutative Algebra are essential. Noetherian rings, the Noether normalisation lemma, integrality, the Hilbert Nullstellensatz and dimension theory will play an important role in the course. B3.3 Algebraic Curves is useful but not essential. Projective spaces and homogeneous coordinates will be defined in C3.4, but a working knowledge of them would be useful. There is some overlap of topics, as B3.3 studies the algebraic geometry of one-dimensional varieties. Courses closely related to C3.4 include C2.2 Homological Algebra, C2.7 Category Theory, C3.7 Elliptic Curves, C2.6 Introduction to Schemes; and partly related to: C3.1 Algebraic Topology, C3.3 Differentiable Manifolds, C3.5 Lie Groups.

Course synopsis: Algebraic geometry is the study of algebraic varieties: an algebraic variety is roughly speaking, a locus defined by polynomial equations. One of the advantages of algebraic geometry is that it is purely algebraically defined and applied to any field, including fields of finite characteristic. It is geometry based on algebra rather than calculus, but over the real or complex numbers it provides a rich source of examples and inspiration to other areas of geometry.

C5.5 Perturbation Methods

Department: Maths

Lecturer: Prof Ruth Baker

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: Knowledge of core complex analysis and of core differential equations will be assumed, respectively at the level of the complex analysis in the Part A (Second Year) course Metric Spaces and Complex Analysis and the phase plane section in Part A Differential Equations I. The final section on approximation techniques in Part A Differential Equations II is highly recommended reading if it has not already been covered.

Course Synopsis: Perturbation methods underlie numerous applications of physical applied mathematics: including boundary layers in viscous flow, celestial mechanics, optics, shock waves, reaction-diffusion equations, and nonlinear oscillations. The aims of the course are to give a clear and systematic account of modern perturbation theory and to show how it can be applied to differential equations.

C6.1 Numerical Linear Algebra

Department: Maths

Lecturer: Prof Yuji Nakatsukasa

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: Only elementary linear algebra is assumed in this course. The Part A Numerical Analysis course would be helpful, indeed some swift review and extensions of some of the material of that course is included here.

Course Synopsis: Linear Algebra is a central and widely applicable part of mathematics. It is estimated that many (if not most) computers in the world are computing with matrix algorithms at any moment in time whether these be embedded in visualization software in a computer game or calculating prices for some financial option. This course builds on elementary linear algebra and in it we derive, describe and analyse a number of widely used constructive methods (algorithms) for various problems involving matrices.

C7.5 General Relativity I

Department: Maths

Lecturer: Dr Christopher Couzens

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: Special Relativity, Classical Mechanics and Electromagnetism

Course Synopsis: The course is intended as an introduction to general relativity, covering both its observational implications and the new insights that it provides into the nature of spacetime and the structure of the universe. Familiarity with special relativity and electromagnetism as covered in the Part A and Part B courses will be assumed. The lectures will review Newtonian gravity, special relativity (from a geometric point of view), and then move on to cover physics in curved space time and the Einstein equations. These will then be used to give an account of planetary motion, the bending of light, the existence and properties of black holes and elementary cosmology.

Groups and Representations

Department: Physics

Lecturer: Prof Andre Lukas

Course Weight: 1.5 units/ 24 lectures

Assessment Method: written exam in HT week 0 and homework completion

Course Synopsis: Modern theories of particle physics are based on symmetry principles and use group theoretical tools extensively. Besides the standard Poincar´e/Lorentz invariance of all such theories, one encounters internal (continuous) groups such as SU(3) in QCD, SU(5) and SO(10) in grand unified theories (GUTs), and E6 and E8 in string theory. Discrete groups also play an important role in particle physics model building, for example in the context of models for fermion masses.
The main purpose of this course is to develop the understanding of groups and their representations, including finite groups and Lie groups.Emphasis is placed on a mathematically satisfactory exposition as well as on applications to physics and practical methods needed for ”routine” calculations.

For a list of prerequisites and suggested reading see here: Groups and Reps outline

Kinetic Theory

Department: Physics

Lecturers: Prof Alex Schekochihin, Dr Paul Dellar and Dr Robert Ewart

Course Weight: 1.75 units/28 lectures

Assessment Method: written exam in week 0 HT or homework completion

Course Synopsis:
Part I (9 lectures). Kinetic theory of gases. Timescales and length scales. Hamiltonian mechanics of N particles. Liouville's Theorem. Reduced distributions. BBGKY hierarchy. Boltzmann-Grad limit and truncation of BBGKY equation for the 2-particle distribution assuming a short-range potential. Boltzmann's collision operator and its conservation properties. Boltzmann's entropy and the H-theorem. Maxwell-Boltzmann distribution. Linearised collision operator. Model collision operators: the BGK operator, Fokker-Planck operator. Derivation of hydrodynamics via Chapman-Enskog expansion. Viscosity and thermal conductivity.
Part II (10 lectures). Kinetic theory of plasmas and quasiparticles. Kinetic description of a plasma: Debye shielding, micro- vs. macroscopic fields, Vlasov-Maxwell equations. Klimontovich's version of BBGKY (non-examinable). Plasma frequency. Partition of the dynamics into equilibrium and fluctuations. Linear theory: initial-value problem for the Vlasov-Poisson system, Laplace-tranform solution, the dielectric function, Landau prescription for calculating velocity integrals, Langmuir waves, Landau damping and kinetic instabilities (driven by beams, streams and bumps on tail), Weibel instability (non-examinable), sound waves, their damping, ion-acoustic instability, ion-Langmuir oscillations. Energy conservation. Heating. Entropy and free energy. Ballistic response and phase mixing. Role of collisions. Elements of kinetic stability theory. Quasilinear theory: general scheme. QLT for bump-on-tail instability in 1D. Introduction to quasiparticle kinetics.
Part III (9 lectures). Kinetic theory of self-gravitating systems. Unshielded nature of gravity and implications for self-gravitating systems. Virial theorem, negative specific heat and impossibility of thermal equilibrium. Escape, impact of fluctuations. Mean-field approximation, angle-action variables, self-consistent potential, biorthonormal potential-density pairs. Relaxation driven by fluctuations in mean-field. Long-time response to initial perturbation. Fokker-Planck equation. Computation of the diffusion coefficients in terms of resonant interactions. Application to a tepid disc.

For further details see here: Kinetic Theory course

Quantum Field Theory

Department: Physics

Lecturer: Prof John Wheater

Course weight: 1.5 units/24 lectures

Assessment method: written exam in 0 HT

Course synopsis:

1. Introduction, and Why do we need quantum field theory?
2. Relativistic wave equations
3. Formalism of classical field theory
4. Canonical quantisation of the real scalar field
5. Charge and complex fields
6. Canonical quantisation of the fermion field
7. Interacting fields, formalism and the perturbation expansion
8. Scattering and decay, their relation to amplitudes
9. Calculation of low order Feynman diagrams
10. Regularization and renormalizable QFTs

Quantum Matter 1: Phases of Matter and Field Theories

Department: Physics

Lecturer: Prof Steve Simon

Course weight: 1 unit/16 lectures

Assessment method: written exam in week 6-8 TT

Course synopsis: This course serves as part of the C6 theory option and also serves as a notional prerequisite for several of the quantum matter courses
(QM2,QM3,QM4) that follow.

Part 1: Phases and Phase Transitions. Phase transitions and Universality. Landau Theory and Applications. Ginzburg-Landau theory: Upper and Lower critical dimensions. Spontaneous Symmetry Breaking. Goldstone modes. Mermin Wagner Theorem.

Part 2: Many Body Quantum Field Theory. Working with Fock Space and Second Quantization. Applications to Fermi Systems, Weakly interating Bosons (Bogoliubov theory) and Spin waves.

Quantum Processes in Hot Plasma

Department: Physics

Lecturer: Prof Peter Norreys

Course weight: 0.75 units/12 lectures

Assessment method: homework completion only

Prerequisites: For MMathPhys students, B3 Quantum Atomic and Molecular Physics. For MSc students, basic atomic physic. The lectures in weeks 1 - 2 of the course reviews the principles of atomic physics from first principles, presented in the B3 course. This is to ensure that students who enrol via the MSc route (external to the University) are brought up to date with those enrolling internally via the Oxford undergraduate physics course.

Course synopsis: Hot plasma is ubiquitous throughout the Universe and first appeared in the epoch of recombination that produced the cosmic background radiation about 378,000 years after the Big Bang. Since then quantum processes, particularly the emission and absorption of electromagnetic radiation from plasma, have provided essential information about the macroscopic structure of matter in the visible Universe. They are key to understanding stellar structure and evolution (along with helioseismology) by providing constraints on radiative transfer associated with nucleosynthesis of chemical elements in stellar interiors and in supernovae explosions. The effort to harness the immense power of nuclear fusion using magnetic or inertial confinement fusion schemes is being actively pursued world-wide. Indeed, these plasmas are among the most intense sources of X-rays in the laboratory and are used to study materials under extreme conditions of density and temperature. Emerging new tools, such as X-ray free electron lasers, are also being applied to these problems for the first time.
This course will introduce the student to the use of quantum mechanics in the computational modelling of hot plasmas. In the first part, an introduction to atomic processes is first provided to remind students of the basic principles of Slater's configurational model and Racah's tensor operator method. Then, the properties of electronic configurations and transition arrays are described, along with how they are used to replace the corresponding sets of individual levels and radiative lines. Following that, we will describe how these are applied to plasma dynamics and atomic processes, along with elegant new methods of super-configurations and effective temperatures. Finally, current applications are described, along with numerical and experimental examples.

B - Hilary Courses

Advanced Fluid Dynamics

Department: Physics

Lecturers: Prof Paul Dellar and Prof Michael Barnes

Course Weight: 1 unit/ 16 lectures

Assessment Method: written exam in week 0 TT or homework completion

General Prerequisites: Basic familiarity with fluid equations and stress tensors as provided, e.g., by Kinetic Theory

Course Synopsis: (Part 1) Low Reynolds number hydrodynamics. The Stokes flow regime, general mathematical results, flow past a sphere. Stresses due to suspended rigid particles. Calculation of the Einstein viscosity for a dilute suspension. Stresses due to Hookean bead-spring dumb-bells. Derivation of the upper convected Maxwell and Oldroyd-B models for viscoelastic fluids. Properties of such fluids. Suspensions of orientable particles, Jeffery's equation, very brief introduction to active suspensions and liquid crystals.
(Part 2) Validity of the MHD approximation. Conservation equations. Magnetic force. Evolution of the magnetic field. MHD waves. Static MHD equilibria. Relaxation. MHD stability (normal modes, energy principle, application to a z-pinch). Non-ideal MHD.

Advanced Quantum Field Theory

Department: Physics

Lecturer: Prof John Wheater (Lectures 1-12), Prof John March-Russell (lectures 13-24)

Course Weight: 1.5 units/24 lectures

Assessment Method: written exam in TT week 0

Prerequisites: Quantum Field Theory (MT), Groups and Representations (MT)

Course Synopsis:

1. Feynman Path integral and generating functionals
2. Quantising the Abelian gauge field, Fadeev-Popov mechanism and ghost fields
3. Scalar and fermionic QED: tree graph processes
4. QED at one loop: dimensional regularization, BRST, Ward identities, renormalization
5. Introduction to non-abelian gauge theory, gauge fixing, Feynman rules and scattering processes in QCD
6. Renormalization group and effective field theory
7. Spontaneous symmetry breaking. The Higgs mechanism.
8. Introduction to non-perturbative QFT: Basics of confinement and chiral symmetry breaking. Solitons

Sequels: The Standard Model and Beyond 1 & 2 (TT), Conformal Field Theory (TT), Quantum Field Theory in Curved Space-Time (TT)

Algorithms and Computations in Theoretical Physics

Department: Physics

Lecturer: Prof Werner Krauth

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Course Synopsis: This course introduces to algorithms and scientific computing from the viewpoint of statistical physics. It is also a practical, example-based, primer on subjects such as Markov chains, molecular dynamics, phase transitions, path integrals, superfluids and Bose-Einstein condensation, among others. The course stresses rigorous foundations and modern developments in mathematics (mixing, non-reversibility, perfect sampling,...) and physics (entropic phase transition, KosterlitzThouless physics, cold atoms,...), yet is entirely based on short Python programs. It will prepare advanced undergraduates in theoretical physics/math for the requirements of modern-day research, with the huge roles played by algorithmic thinking and by statistics, both with their power, their paradoxes and their intricacies.

For further details see here: course page

C3.2 Geometric Group Theory

Department: Maths

Lecturer: Prof Panos Papazoglou

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: Some familiarity with Cayley graphs, fundamental group and covering spaces (as for example in the course B3.5 Topology & Groups) would be a helpful though not essential prerequisite.

Course Synopsis: The aim of this course is to introduce the fundamental methods and problems of geometric group theory and discuss their relationship to topology and geometry. The first part of the course begins with an introduction to presentations and the list of problems of M. Dehn. It continues with the theory of group actions on trees and the structural study of fundamental groups of graphs of groups.The second part of the course focuses on modern geometric techniques and it provides an introduction to the theory of Gromov hyperbolic groups.

C3.5 Lie Groups

Department: Maths

Lecturer: Prof Pierrick Bousseau

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: ASO: Group Theory, A5: Topology and ASO: Multidimensional Analysis and Geometry are all useful but not essential. It would be desirable to have seen notions of derivative of maps from Rn to Rm, inverse and implicit function theorems, and submanifolds of Rn. Acquaintance with the notion of an abstract manifold would be helpful but not really necessary.

Course Synopsis: The theory of Lie Groups is one of the most beautiful developments of pure mathematics in the twentieth century, with many applications to geometry, theoretical physics and mechanics. The subject is an interplay between geometry, analysis and algebra. Lie groups are groups which are simultaneously manifolds, that is geometric objects where the notion of differentiability makes sense, and the group multiplication and inversion are differentiable maps. The majority of examples of Lie groups are the familiar groups of matrices. The course does not require knowledge of differential geometry: the basic tools needed will be covered within the course.

C3.11 Riemannian Geometry

Department: Maths

Lecturer: Prof Andrew Dancer

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: Differentiable Manifolds is required. An understanding of covering spaces will be strongly recommended.
Course Synopsis: Riemannian Geometry is the study of curved spaces and provides an important tool with diverse applications from group theory to general relativity. The surprising power of Riemannian Geometry is that we can use local information to derive global results. This course will study the key notions in Riemannian Geometry: geodesics and curvature. Building on the theory of surfaces in R3 in the Geometry of Surfaces course, we will describe the notion of Riemannian

submanifolds, and study Jacobi fields, which exhibit the interaction between geodesics and curvature. We will prove the Hopf--Rinow theorem, which shows that various notions of completeness are equivalent on Riemannian manifolds, and classify the spaces with constant curvature.The highlight of the course will be to see how curvature influences topology. We will see this by proving the Cartan--Hadamard theorem, Bonnet--Myers theorem and Synge's theorem.

C3.12 Low-dimensional Topology and Knot Theory

Department: Maths

Lecturer: Prof Andras Juhasz

Course Weight: 1 unit/ 16 lectures

Assessment Method: written exam in TT

General Prerequisites: B3.5 Topology and Groups (MT) and C3.1 Algebraic Topology (MT) are essential. We will assume working knowledge of the fundamental group, covering spaces, homotopy, homology, and cohomology. B3.2 Geometry of Surfaces (MT) and C3.3 Differentiable Manifolds (MT) are useful but not essential, though some prior knowledge of smooth manifolds and bundles should make the material more accessible.

Course synopsis: Low-dimensional topology is the study of 3- and 4-manifolds and knots. The classification of manifolds in higher dimensions can be reduced to algebraic topology. These methods fail in dimensions 3 and 4. Dimension 3 is geometric in nature, and techniques from group theory have also been very successful. In dimension 4, gauge-theoretic techniques dominate.This course provides an overview of the rich world of low-dimensional topology that draws on many areas of mathematics. We will explain why higher dimensions are in some sense easier to understand, and review some basic results in 3- and 4-manifold topology and knot theory.

C5.4 Networks

Department: Maths

Lecturer: Prof Peter Grindrod

Course Weight: 1 unit/16 lectures

Assessment Method: mini-project

General prerequisites: Basic notions of linear algebra, probability, dynamical systems, and some computational experience. The student may use the language of their choice for computational experiments. Relevant notions of graph theory will be reviewed and illustrated.

Course Synopsis: Network Science provides generic tools to model and analyse systems in a broad range of disciplines, including biology, computer science and sociology. This course aims at providing an introduction to this interdisciplinary field of research, by integrating tools from graph theory, statistics and dynamical systems. Most of the topics to be considered are active modern research areas. This year the course has been altered to incorporate some new material on dynamically evolving networks and the analysis of scaling properties of growing networks.

C5.6 Applied Complex Variables

Department: Maths

Lecturer: Prof James Oliver

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: The course requires second year core analysis (A2 complex analysis). It continues the study of complex variables in the directions suggested by contour integration and conformal mapping. A knowledge of the basic properties of Fourier Transforms is assumed. Part A Waves and Fluids and Part C Perturbation Methods are helpful but not essential.

Course synopsis: The course begins where core second-year complex analysis leaves off, and is devoted to extensions and applications of that material. The solution of Laplace's equation using conformal mapping techniques is extended to general polygonal domains and to free boundary problems. The properties of Cauchy integrals are analysed and applied to mixed boundary value problems and singular integral equations. The Fourier transform is generalised to complex values of the transform variable, and used to solve mixed boundary value problems and integral equations via the Wiener-Hopf method.

C7.4 Intro to Quantum Information

Department: Maths

Lecturer: Prof Artur Ekert

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: Quantum Theory. The course material should be of interest to physicists, mathematicians, computer scientists, and engineers. The following will be assumed as prerequisites for this course:
- elementary probability, complex numbers, vectors and matrices; - Dirac braket notation; - a basic knowledge of quantum mechanics especially in the simple context of finite dimensional state spaces (state vectors, composite systems, unitary matrices, Born rule for quantum measurements); - basic ideas of classical theoretical computer science (complexity theory) would be helpful but are not essential. Prerequisite notes will be provided giving an account of the necessary material. It would be desirable for you to look through these notes slightly before the start of the course.

Course Synopsis: The classical theory of computation usually does not refer to physics. Pioneers such as Turing, Church, Post and Goedel managed to capture the correct classical theory by intuition alone and, as a result, it is often falsely assumed that its foundations are self-evident and purely abstract. They are not! Computers are physical objects and computation is a physical process. Hence when we improve our knowledge about physical reality, we may also gain new means of improving our knowledge of computation. From this perspective it should not be very surprising that the discovery of quantum mechanics has changed our understanding of the nature of computation. In this series of lectures you will learn how inherently quantum phenomena, such as quantum interference and quantum entanglement, can make information processing more efficient and more secure, even in the presence of noise.

C7.6 General Relativity II

Department: Maths

Lecturer: Dr Christopher Couzens

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

Prerequisites: C7.5 General Relativity I

Course synopsis: In this, the second course in General Relativity, we have two principal aims. We first aim to increase our mathematical understanding of the theory of relativity and our technical ability to solve problems in it. We apply the theory to a wider class of physical situations, including gravitational waves and black hole solutions. Orbits in the Schwarzschild solution are given a unified treatment which allows a simple account of the three classical tests of Einstein's theory. This leads to a greater understanding of the Schwarzschild solution and an introduction to its rotating counterpart, the Kerr solution. We analyse the extensions of the Schwarzschild solution show how the theory of black holes emerges and exposes the radical consequences of Einstein's theory for space-time structure.

C7.7 Random Matrix Theory

Department: Maths

Lecturer: Prof Louis-Pierre Arguin

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

General Prerequisites: There are no formal prerequisites, but familiarity with basic concepts and results from linear algebra and probability will be assumed, at the level of A0 (Linear Algebra) and A8 (Probability).

Course synopsis: Random Matrix Theory provides generic tools to analyse random linear systems. It plays a central role in a broad range of disciplines and application areas, including complex networks, data science, finance, machine learning, number theory, population dynamics, and quantum physics. Within Mathematics, it connects with asymptotic analysis, combinatorics, integrable systems, numerical analysis, probability, and stochastic analysis. This course aims to provide an introduction to this highly active, interdisciplinary field of research, covering the foundational concepts, methods, questions, and results.

Collisionless Plasma Physics

Department: Physics

Lecturer: Dr Daniel Kennedy and Dr Plamen Ivanov

Course Weight: 1 unit/18 lectures

Assessment Method: take-home exam or homework completion

General Prerequisites: Kinetic Theory (MT), an undergraduate course on Electricity and Magnetism
Course Synopsis:
Part I. Plasma waves:
Cold plasma waves in a magnetised plasma. WKB theory of cold plasma wave propagation in an inhomogeneous plasma, cut-offs and resonances. Hot plasma waves in a magnetised plasma. Cyclotron resonance.
Part II. Kinetics of strongly magnetised plasmas:
Kinetic description of a collisionless, magnetised plasma; kinetic MHD. Barnes damping, firehose and mirror instabilities. Particle motion. Drift kinetics. Drift waves and the ion-temperature-gradient instability. Electron drift kinetics (time permitting): kinetic Alfvén waves, electron-temperature-gradient instabilities.

Cosmology

Department: Physics

Lecturer: Dr David Alonso

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

Prerequisites: General Relativity I (MT) or equivalent.

Einstein field equations and the Friedman equations, universe models, statistics of expanding background, relativistic cosmological perturbations, observations, from the Hubble flow to the CMB.

Galactic and Planetary Dynamics

Department: Physics

Lecturer: Prof John Magorrian

Course Weight: 1 unit/16 lectures

Assessment Method: TBC

Prerequisites: Kinetic Theory (MT)

Course Synopsis: Review of Hamiltonian mechanics. Orbit integration. Classification of orbits and integrability. Construction of angle-action variables. Hamiltonian perturbation theory. Simple examples of its application to the evolution of planetary and stellar orbits. Methods for constructing equilibrium galaxy models. Applications. Fundamentals of N-body simulation. Dynamical evolution of isolated galaxies. Interactions with companions.

Geophysical Fluid Dynamics

Department: Physics

Lecturer: Prof Tim Woollings

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in TT

Course Synopsis: Rotating frames of reference. Geostrophic and hydrostatic balance. Pressure coordinates. Shallow water and reduced gravity models, f and β–planes, potential vorticity. Inertia-gravity waves, dispersion relation, phase and group velocity. Rossby number, equations for nearly geostrophic motion, Rossby waves, Kelvin waves. Linearised equations for a stratified, incompressible fluid, internal gravity waves, vertical modes. Quasigeostrophic approximation: potential vorticity equation, Rossby waves, vertical propagation and trapping. Eady model of baroclinic instability. Overview of large-scale structure and circulation of atmospheres and oceans, poleward heat transport. Angular momentum and Held-Hou model of Hadley circulations. Applications to Mars and slowly-rotating planets. Tide-locked exoplanets. Giant planets: Multiple jets, stable eddies and free modes.

High Energy Density Plasma Physics

Department: Physics

Lecturer: Prof Peter Norreys and Dr Ramy Aboushelbaya

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Course Synopsis: In this course, the topics will be introduced for first principles. The student will be taken through the fundamental physics of laser energy absorption in matter up to and including the new laser QED plasma regime at extreme intensities. The student will be introduced to hydrodynamic motion via first principles derivation of the Navier-Stokes equations as well as compression and rarefaction waves. Then a thorough grounding in hydrodynamic instabilities will be provided, including the Rayleigh-Taylor instability and the applications of linear theory. This will be followed by the extension to the convective instability; mode coupling; the Kelvin-Helmholtz; shock stability and the Richtmyer-Meshkov instability. The behaviour of shock waves in one dimension will then be discussed, including the derivation of the Rankine-Hugoniot equations; the effects of boundaries and interfaces; blast waves and shocks in solids. Following that, the physics of convergent shocks will be described. These include homogeneous expansion/contraction self-similar flows as well as shock dynamics. The hydrodynamic behaviour is governed by the equations of state including thermodynamic properties, so the student will be introduced to equations of state for gases, plasmas, solids and liquids. For thermal energy transport, the thermal energy transport equation is derived, as are the effects of the conductivity coefficients, inhibited thermal transport, electron-ion energy exchange, before electron degeneracy effects are introduced. The physics of radiation energy transport will be described, including radiation as a fluid and the Planck distribution function; radiation flux definition; solutions to the radiation energy transfer equations; material opacities; non-LTE radiation transport; radiation dominated hydrodynamics. Finally, dimensionless scaling laws for hydrodynamics will be outlined, ones that provide the student with a link between the fascinating detailed microphysics of laboratory plasma phenomena and exquisite astrophysical observations.

Nonequilibrium Statistical Physics

Department: Physics

Lecturer: Prof Ramin Golestanian

Course Weight: 1 unit/16 lectures

Assessment Method: TBC

Course Synopsis: Stochastic Langevin dynamics. Brownian motion. Nonequilibrium kinetics. Master equation. Fokker-Planck equation. Kramers rate theory and mean first-passage time. Brownian ratchets. Multiplicative noise. Path integral formulation and Martin-Siggia-Rose method. Fluctuation theorems.

Quantum Matter 2: Quantum Fluids

Department: Physics

Lecturer: Prof Sid Parameswaran

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in week 0 TT or homework completion

Course Synopsis: "Quantum fluids" are systems of many interacting particles where the role of quantum statistics is significant, and can lead to macroscopic quantum effects. This courses focuses on the simplest examples, ones where Galilean invariance is a good approximation, i.e. the role of crystal lattices or imperfections is ignored. We will first discuss phenomenological and microscopic models of superfluids of bosons (such as Helium 4), before discussing the case of charged superfluids. This will lead us naturally into discussions of the Meissner effect and the Anderson-Higgs mechanism. To describe electronic superconductors (or paired sermonic superfluids such as Helium 3) microscopically, we will first need to take a detour through the theory of the interacting electrons gas and Landau's theory of Fermi liquids, before discussing the Bardeen-Cooper-Schrieffer theory. Time permitting, the course will close with a discussion of arguably the most exotic quantum fluids discovered to date: the two-dimensional quantum Hall liquids that form out of electron gases placed in high magnetic fields, which give rise to fractional charge.

Quantum Matter 3: Quantum Dynamics and Information in Many-particle Systems

Department: Physics

Lecturer: Prof Fabian Essler

Course Weight: 1 unit/16 lectures (continues in Trinity term)

Assessment Method: written exam in week 0 TT or homework completion

Course Synopsis:

1 Elements of Quantum Statistical Mechanics
1.1 Pure and Mixed States, (Reduced) Density Matrices
1.2 Entropy, Ensembles and Typicality
2 Eigenstates of Local Many-Particle Hamiltonians
2.1 Tight-Binding Model of Spinless Fermions
2.2 Entanglement Measures
2.3 Entanglement Entropy of Energy Eigenstates
2.4 The Spin-1 Aklt Chain
2.5 Matrix Product State Methods
2.6 Symmetry Protected Topological Order
3 Quantum Many-Particle Dynamics
3.1 Quantum Quenches
3.2 (Generalized) Thermalization
3.3 Eigenstate Thermalization Hypothesis
3.4 Bbgky Hierarchy
3.5 Self-Consistent Time-Dependent Mean-Field Approximation
3.6 Quantum Boltzmann Equation
4 Open and Driven Quantum Systems
4.1 Quantum Master Equations
4.2 Periodically Driven Systems And Quantum Circuits

String Theory I

Department: Maths

Lecturer: Prof Xenia de la Ossa

Course Weight: 1 unit/16 lectures

Assessment Method: TBC

Prerequisites: Quantum Field Theory (MT)

Course Synopsis: Historical background, Dolen-Horn-Schmid duality, the Veneziano and Virasoro-Shapiro amplitudes. Nambu-Goto and Polyakov world-sheet actions, equations of motion and constraints, open and closed strings and their corresponding boundary conditions. Old covariant quantization: the Virasoro algebra, physical state conditions, ghosts, critical spacetime dimension, and spacetime particle spectrum. Basic considerations of light-cone gauge quantization. Vertex operators and string scattering amplitudes. Strings in background fields, spacetime effective action. Circle compactification, elementary consideration of D-branes, T-duality.

Supersymmetry and Supergravity

Department: Maths

Lecturer: Dr Michele Levi

Course Weight: 1 unit/16 lectures

Assessment Method: written exam in week 0 TT

Course Synopsis:
1. Context and Motivation.
2. Spinors Preliminary.
3. Supersymmetry Algebra.
4. Superspace and Superfields.
5. Chiral Superfields and Supersymmetric Actions.
6. Supersymmetric Gauge Theories.
7. Spontaneous Symmetry Breaking.

C - Trinity Courses

Advanced Topics in Plasma Physics

Department: Physics

Lecturer: Dr Daniel Kennedy

Course Weight: 0.75 units/12 lectures

Assessment Method: homework completion only

Course Synopsis: Basics of magnetic-confinement fusion. Magnetic geometry and flux surfaces in toroidal devices. Equilibrium vs fluctuations. Scale separation in time and space.
Asymptotic expansion the Vlasov-Landau equation. Gyrokinetic variables and gyroaverages. Derivation of the gyrokinetic equilibrium. Equilibrium Maxwell's equations. Derivation of the gyrokinetic equation for plasma fluctuations. Fluctuating Maxwell's equations. Free-energy conservation in gyrokinetics.Plasma instabilities. Linear gyrokinetic theory and temperature-gradient-driven instabilities.

Astroparticle Physics

Department: Physics

Lecturer: Prof Joseph Conlon

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Pre-requisites: Quantum Field Theory (MT), General Relativity I (MT)

Course synopsis: The Universe observed, constructing world models, reconstructing our thermal history, decoupling of the cosmic microwave background, primordial nucleosynthesis. Dark matter: astrophysical phenomenology, relic particles, direct and indirect detection. Cosmic particle accelerators, cosmic ray propagation in the Galaxy. The energy frontier: ultrahigh energy cosmic rays and neutrinos. The early Universe: constraints on new physics, baryo/leptogenesis, inflation, the formation of large-scale structure, dark energy.

Collisional Plasma Physics

Department: Physics

Lecturer: Prof Alex Schekochihin

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Prerequisites: Kinetic Theory (MT), Advanced Fluid Dynamics (HT), Collisionless Plasma Physics (HT)

Course Synopsis: Collision operators: Fokker-Plank collision operator, conservation properties, entropy, electron-ion and ion-electron collisions, linearized collision operator. Collisional transport (Braginskii equations: derivation of Spitzer resistivity and electron heat conduction, ion heat conduction and viscosity. Resistive MHD: tearing modes, magnetic reconnection. Introduction to tokamak theory: Pfirsch-Schlueter collision transport regime for electrons.

Conformal Field Theory

Department: Maths

Lecturer: Prof Robin Karlsson

Course Weight: 1 unit/16 hours

Assessment Method: homework completion only

Prerequisites: Quantum Field Theory (MT)

Course Synopsis:
- Motivation: RG flows and scale invariance.
- Conformal transformations.
- Consequence of conformal invariance.
- Radial quantization and the operator algebra.
- Conformal invariance in two dimensions.
- The Virasoro algebra.
- Minimal models.
- Conformal bootstrap in d > 2.

Machine Learning Fundamentals with Applications to Physics and Mathematics

Department: Physics

Lecturer: Dr Andrei Constantin

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Prerequisites: Prior exposure to Mathematica and Python will be helpful, but not mandatory.

Course Synopsis: Over the past five to ten years, machine learning and artificial intelligence in general, have evolved into indispensable research tools. This course seeks to offer a comprehensive introduction to the diverse array of machine learning techniques. These methods share the common goal of crafting algorithms that enable computers to make predictions and decisions autonomously, without relying on explicit, handcrafted rules. Using these techniques, one can extract valuable insights from computers that surpass the information initially provided.
The course will discuss fundamental principles, algorithms, and a number of applications in Mathematics and Physics, including state reconstruction in quantum physics, model building in particle physics and cosmology, applications to string theory compactifications, conformal bootstrap and knot theory.

Quantum Field Theory in Curved Space-Time

Department: Maths

Lecturer: Dr Pieter Bomans

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Prerequisites: Quantum Field Theory (MT), General Relativity I (MT) and General Relativity II (HT). Advanced Quantum Field Theory and a course on differential geometry will be helpful but not essential.

Course Synopsis: This course builds on the courses in quantum field theory and general relativity. It will focus on classical and quantum aspects of fields in curved space-time. The course will consist of the following topics: Classical fields in curved space, Quantization in curved space, Quantum fields in (Anti) de Sitter space, Quantum fields in Rindler space and the Unruh effect, Hawking radiation, Black hole thermodynamics and the Hawking-Page phase transition, Interactions in curved space-time, Quantum field theory and cosmology.

Quantum Matter 4: Renormalization and Bosonization

Department: Physics

Lecturer: Prof Shivaji Sondhi

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Prerequisites: Although the lectures will be self-contained, this course is designed as a follow-on to Quantum Matter II. Familiarity with ideas introduced in Advanced Quantum Theory and Renormalization Group will be useful but not essential.

Course synopsis: Modern condensed matter physics is increasingly focused on understanding the properties of strongly interacting systems. Traditional techniques that rely on diagrammatic perturbation theory about the independent electron approximation are often insufficient to provide an adequate description of the rich phenomena possible in this setting. Instead, their study requires a variety of ideas often also invoked in the study of quantum field theories in the non-perturbative regime. This course will cover two of these ideas: the renormalization group and (abelian) bosonization.

Renormalization group for Interacting Fermions: momentum-shell RG for φ^4 theory; RG and the Fermi surface; BCS and CDW as competing instabilities; RG in d=1 and emergence of Luttinger liquids

Bosonization: Fermion-boson dictionary; application to spinless fermions; sine-Gordon model and Kosterlitz-Thouless flow; emergence of insulators from commensuration

Renormalisation Group

Department: Maths

Lecturer: Prof Fernando Alday

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Prerequisites: Quantum Field Theory (MT), C5.3 Statistical Mechanics (HT) or equivalent

Course Synopsis: This course introduces ideas of scale-invariance and the renormalisation group in statistical physics, using simple lattice models and field theories as examples. Topics include: Real space RG; Fixed points, scaling operators, operator product expansion etc.; Landau Ginsburg theory; Mean field theory; Large N approximation; the 4-epsilon expansion; the 2+epsilon expansion; the Kosterlitz-Thouless transition; The Sine-Gordon model; XY duality.

String Theory II

Deaprtment: Maths

Lecturer: Prof Xenia de la Ossa

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

General Prerequisites: Quantum Field Theory (MT), String Theory I (HT) , Advanced Quantum Field Theory (HT), Supersymmetry and Supergravity (HT)

Course Synopsis: Classical superstring action, RNS string, quantization and GSO-projection; 10d superstrings: Type IIA, IIB, I and Heterotic strings; Open strings and D-branes; Supergravities and spacetime effective actions, M-theory and 11d supergravity; Compactifications; Dualities between string theories.

The Standard Model and Beyond I

Department: Physics

Lecturer: TBC

Course Weight: 1 unit/ 16 lectures

Assessment Method: homework completion only

Prerequisite: Advanced Quantum Field Theory (HT)

Course Synopsis: Basics of strong interactions: the peculiarities of asymptotic freedom and the uniqueness of gauge theories. Low-energy effective actions: from QCD to the chiral Lagrangian, and Effective Field Theories. Building the Electroweak sector of the Standard Model. Exploring the structure of the Electroweak sector. QCD at colliders [if time permits]: OPE and factorisation, from hadrons to partons
You may find the following textbooks useful: H. Georgi, Weak Interactions and Modern Particle Theory; J.F. Donoghue, E. Golowich, Barry R. Holstein, Dynamics of the standard model.

The Standard Model and Beyond II

Department: Physics

Lecturer: Prof John March-Russell

Course Weight: 1 unit/16 lectures

Assessment Method: homework completion only

Prerequisite: Advanced Quantum Field Theory (HT)

Topics in Soft and Activer Matter Physics

Department: Physics

Lecturer: Prof Ard Louis

Course Weight: 0.5 units/8 lectures

Assessment Method: homework completion only

Prerequisites: Advanced Fluid Dynamics (HT)

Course Synopsis:
This is a reading course. Under the guidance of the course organiser, students will give presentations based on key papers in soft condensed matter theory. Some examples of the topics for these presentations are: Active nematics and active gels. Wetting, spreading and contact line dynamics. Hydrodynamics of microswimmers: Stokes equation, scallop theorem, multipole expansion, active suspensions. Fluctuations and response.

D - Assessment Methods by Course

MICHAELMAS					
Course Title	**Units**	**Assessment Method**	**Assessment Instruction**	**Assessment Date/Deadline**	**Exam Entry**
Advanced Philosophy of Physics	1.5	mini-project *OR* *homework completion*	Released Fri 4HT *N/A*	noon Fri 4TT *N/A*	7 - 14 May 26 *22-29 Jan 26*
Anyons and Topological Quantum Field Theory	1	in-person exam *OR* *homework completion*	2hrs (2 of 2 questions) *N/A*	0 HT *N/A*	30 Oct - 7 Nov 25 *22-29 Jan 26*
C3.1 Algebraic Topology	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C3.3 Differentiable Manifolds	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C3.4 Algebraic Geometry	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C5.5 Perturbation Methods	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C6.1 Numerical Linear Algebra	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C7.5 General Relativity I	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
Dissertation (single)	1	dissertation	30 pages	Mon 6TT	7 - 14 May 26
Dissertation (double unit)	2	dissertation	60 pages	Mon 6TT	7 - 14 May 26
Groups and Representations	1.5	in-person exam **AND** **homework completion**	3hrs (3 of 3 questions) **N/A**	0 HT **N/A**	30 Oct - 7 Nov 25 **22-29 Jan 26**
Kinetic Theory	1.75	in-person exam *OR* *homework completion*	3hrs (3 of 3 questions) *N/A*	0 HT *N/A*	30 Oct - 7 Nov 25 *22-29 Jan 26*
Quantum Field Theory	1.5	in-person exam	3hrs (3 of 3 questions)	0 HT	30 Oct - 7 Nov 25
Quantum Matter 1: Phases of Matter and Field Theories	1	in-person exam	2hrs (2 of 2 questions)	6-8TT	22-29 Jan 26
Quantum Processes in Hot Plasma	0.75	homework completion	N/A	N/A	22-29 Jan 26

HILARY					
Course Title	**Units**	**Assessment Method**	**Assessment Instruction**	**Assessment Date/Deadline**	**Exam Entry**
Advanced Fluid Dynamics	1	in-person exam *OR* *homework completion*	2hrs (2 of 2 questions) *N/A*	0TT *N/A*	22-29 Jan 26 *7-14 May 26*
Advanced QFT	1.5	in-person exam	3hrs (3 of 3 questions)	0TT	22-29 Jan 26
Algorithms and Computations in Theoretical Physics: a Set of Lectures	1	homework completion	N/A	N/A	7-14 May 26
C3.11 Riemannian Geometry	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C3.12 Low-Dimensional Topology and Knot Theory	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C3.2 Geometric Group Theory	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C3.5 Lie Groups	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C5.4 Networks	1	mini-project	Released Fri 8HT	Fri -1TT	22-29 Jan 26
C5.6 Applied Complex Variables	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C7.4 Intro to Quantum Information	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C7.6 General Relativity II	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
C7.7 Random Matrix Theory	1	in-person exam	1hr 45 (2 of 2 questions)	6-8TT	22-29 Jan 26
Collisionless Plasma Physics	1	take-home exam *OR* *homework completion*	Released Fri 8HT *N/A*	Wed 9HT *N/A*	22-29 Jan 26 *7-14 May 26*
Cosmology	1	in-person exam	2hrs (2 of 2 questions)	6-8TT	22-29 Jan 26
Galactic and Planetary Dynamics	1	mini-project *OR* *homework completion*	Released Fri 8HT *N/A*	Fri 11HT *N/A*	22-29 Jan 26 *7-14 May 26*
Geophysical Fluid Dynamics	1	in-person exam	2hrs (2 of 2 questions)	6-8TT	22-29 Jan 26
High Energy Density Plasma Physics	1	homework completion	N/A	N/A	7-14 May 26
Nonequilibrium Statistical Physics	1	in-person exam *OR* *homework completion*	2hrs (2 of 2 questions) *N/A*	0TT *N/A*	22-29 Jan 26 *7-14 May 26*
Quantum Matter 2: Quantum Fluids	1	in-person exam *OR* *homework completion*	2hrs (2 of 2 questions) *N/A*	0TT *N/A*	22-29 Jan 26 *7-14 May 26*
Quantum Matter 3: Quantum Dynamics and Information in Many-particle Systems	1	homework completion	N/A	N/A	7-14 May 26
String Theory I	1	in-person exam	2hrs (2 of 2 questions)	0TT	22-29 Jan 26
Supersymmetry & Supergravity	1	in-person exam	2hrs (2 of 2 questions)	0TT	22-29 Jan 26

TRINITY					
Course Title	**Units**	**Assessment Method**	**Assessment Instruction**	**Assessment Date/Deadline**	**Exam Entry**
Advanced Topics in Plasma Physics	0.75	homework completion	N/A	N/A	7-14 May 26
Astroparticle Physics	1	homework completion	N/A	N/A	7-14 May 26
Collisional Plasma Physics	1	homework completion	N/A	N/A	7-14 May 26
Conformal Field Theory	1	homework completion	N/A	N/A	7-14 May 26
Machine Learning Fundamentals with Applications to Physics and Mathematics	1	homework completion	N/A	N/A	7-14 May 26
Quantum Field Theory in Curved Space	1	homework completion	N/A	N/A	7-14 May 26
Quantum Matter 4: Renormalization and Bosonization	1	homework completion	N/A	N/A	7-14 May 26
Renormalisation Group	1	homework completion	N/A	N/A	7-14 May 26
String Theory II	1	homework completion	N/A	N/A	7-14 May 26
The Standard Model and Beyond I	1	homework completion	N/A	N/A	7-14 May 26
The Standard Model and Beyond II	1	homework completion	N/A	N/A	7-14 May 26
Topics in Soft and Active Matter Physics	0.5	homework completion	N/A	N/A	7-14 May 26

E - Dissertation Topics

Subject to Joint Supervisory Committee approval

Supervisor: Prof Alexander Schekochihin

(alex.schekochihin@physics.ox.ac.uk)

Title: Thermodynamics, Statistical Physics, and Effective Collision Integrals for Collisionless Plasma

Abstract:
Ordinary gases and plasmas where binary collisions between particles occur on time scales that are shorter than the time scales of collective dynamics usually hover close to Maxwellian equilibria — an expression of the thermodynamical inevitability ubiquitous in nature. What, however, happens if the collisions are infrequent, like they are in many astrophysical plasmas (and also in most gravitating kinetic systems)? The question has been on the agenda since the 1960s but in recent years, there have been a number of interesting developments that suggest a path forward, previously obscure. It turns out that the principle of maximum entropy can be applied to such systems if one treats the particle distribution function (phase-space density) itself as a random field and asks how its coarse-grained (averaged) version evolves subject to constraints imposed by (approximate) incompressibility of the phase space (encoded in a continuum of Casimir invariants). Universal equilibria emerge — they can be derived by the methods of statistical mechanics (maximising entropy), but a further challenge is to do to the resulting equilibria what Boltzmann did to Maxwell's distribution and work out how (and why) they are achieved dynamically. This means deriving, essentially, an effective field theory for the evolution of non-Maxwellian plasmas — "collisionless collision integrals". Under some rather restrictive assumptions, this has been done for Vlasov-Poisson (electrostatic plasmas). The student's first task would be to learn the necessary theory that leads one to that point. From there, they will be looking over the research frontier into terra incognita. A useful research-level task would be to work out how (and whether) the existing theory can be generalised to Vlasov-Maxwell (electromagnetic) plasmas. Another would be to try some new approaches to deriving collision integrals beyond the quasilinear approximation. It is also possible that, in the course of their exploration of the subject, the student might tread onto a third path, which cannot as yet be predicted.

Reading:
D. Lynden-Bell, "Statistical mechanics of violent relaxation in stellar systems," Mon. Not. R. Astron. Soc. 136, 101 (1967)
T. H. Dupree, "Theory of phase space density granulation in plasma," Phys. Fluids 15, 334 (1972)
R. J. Ewart et al., "Collisionless relaxation of a Lynden-Bell plasma," J. Plasma Phys. 88, 925880501 (2022)
R. J. Ewart et al., "Non-thermal particle acceleration and power-law tails via relaxation to universal Lynden-Bell equilibria," J. Plasma Phys. 89, 905890516 (2023)
A. A. Schekochihin, "Lectures on Kinetic Theory and Magnetohydrodynamics of Plasmas", secs 10-11 and references therein, https://www-thphys.physics.ox.ac.uk/people/AlexanderSchekochihin/KT/2015/KTLectureNotes.pdf

Title: Phase-Space Structures and Strong Langmuir Turbulence

Abstract:
This dissertation is related to the previous one: the relaxation of collisionless plasmas towards universal non-Maxwellian equilibria occurs because the plasma is in a turbulent state that is very different from thermal (particle) noise that underlies the relaxation of collisional systems to the local Maxwellian equilibrium. This turbulence occurs in a 6D phase space and has only recently started to be understood theoretically and probed numerically. An especially fascinating (and, it seems, highly consequential) feature of it appears to be that, due to the phenomenon of particle trapping in electric fluctuations, long-lived coherent structures can form and then engage in vigorous dynamics, interacting with each other, growing to ever-larger size at each other's expense, and in the process stirring the plasma in a manner that pushes it towards non-Maxwellian states. In this dissertation, the student will first study the fundamental theory underlying our understanding of these structures and then, if they (the student) have sufficient energy and gain sufficient momentum while there is still time, they can attempt to construct a theory of turbulence of phase-space structures. A promising lead is that it will turn out to be linked to the theories of strong Langmuir turbulence developed in the 1970s-80s, but never finished due to impossibility at that time of testing ideas on large computers (which are now available and have yielded some intriguing new data).

Reading:

I. B. Bernstein et al., "Exact nonlinear plasma oscillations," Phys. Rev. 108, 546 (1957)
T. O'Neil, "Collisionless damping of nonlinear plasma oscillations," Phys. Fluids 8, 2255 (1965)
I. H. Hutchinson, "Kinetic solitary electrostatic structures in collisionless plasma: phase-space holes,", arXiv:2407.08539 (2024)
M. L. Nastac et al., "Phase-space entropy cascade and irreversibility of stochastic heating in nearly collisionless plasma turbulence," Phys. Rev. E 109, 065210 (2024)
A. A. Schekochihin, "Lectures on Kinetic Theory and Magnetohydrodynamics of Plasmas", secs 8, 12 and references therein (on strong Langmuir turbulence, see references in sec. 8.6.2), https://www-thphys.physics.ox.ac.uk/people/AlexanderSchekochihin/KT/2015/KTLectureNotes.pdf

Supervisor: Prof Andre Henriques

(henriques@maths.ox.ac.uk)

Title: The Virasoro Algebra

Abstract:
The Virasoro algebra is an important infinite dimensional Lie algebra, with a rich and fascinating representation theory. It is the universal central extension of the Lie algebra of vector fields on the circle, and plays a central important role in two-dimensional conformal field theory. The proposal will start with an investigation of Lie algebra cohomology, specifically the relation between H^2 and Lie algebra central extensions. Then, a specific construction called the Segal-Sugawara construction will be investigated: every representation of a so-called affine Lie algebra is automatically also a representation of the Virasoro algebra. At last, we will aim for a classification of the irreducible representations of the Virasoro algebra. An ambitious (optional) goal would be to study the so-called fusion product of representations of the Virasoro algebra, which equips the category of representations of the Virasoro algebra with the structure of a modular tensor category. (Note: initial supervision for this project may be held in groups.)

Pre-requisites:
B2.3 Lie Algebras
Recommended:
C2.2 Homological Algebra
C2.3 Representation Theory of Semisimple Lie Algebras

Reading:
Course notes: http://andreghenriques.com/Teaching/CFT-2020.pdf
A Mathematical Introduction to Conformal Field Theory, by M. Schottenloher.
V. G. Kac. Infinite-dimensional Lie algebras. Cambridge University Press.
Unitary representations of the Virasoro and super-Virasoro algebras, by P. Goddard, A. Kent, and D. Olive
Conformal Field Theory, by David Sénéechal, Philippe Francesco, and Pierre Mathieu
Representation Theory of the Virasoro Algebra, by Kenji Iohara, and Yoshiyuki Koga.
Friedan, D., Qiu, Z.A. and Shenker, S.H., 1984. Conformal invariance, unitarity and two-dimensional critical exponents. Physical Review Letters, 52, p.1575.
Wang, W., 1993. Rationality of Virasoro vertex operator algebras. International Mathematics Research Notices, 1993(7), pp.197-211.

Supervisor: Prof Andrew Dancer

(dancer@maths.ox.ac.uk)

Title: Symplectic Geometry and Quantisation

Abstract:
This project would explore aspects of symplectic geometry, especially those related to group actions on symplectic manifolds. The project would start with a review of the basic theory of symplectic manifolds, Hamiltonian group actions and moment maps. Further topics could include all or some of the following: (i) Abelian actions, toric varieties and Delzant's theorem. (ii) moment maps and symplectic reduction (iii) Duistermaat-Heckman theorem (iii) geometric quantisation of symplectic manifolds, in particular a detailed treatment of the case of Delzant spaces There are many examples in toric

geometry that could be workedout, and quite a few details that he candidate could fill in during an exploration of the literature. There are extensive links with convex geometry, combinatorics and even some parts of number theory.

Prerequisites:
It would be helpful to take Differentiable Manifolds and C3.5 Lie Groups

Reading:
V. Guillemin. Moment Maps and Combinatorial Invariants of Hamiltonian T n Spaces (Birkhauser). M. Audin.
The Topology of Torus Actions on Symplectic Manifolds (Birkhauser).

Supervisor: Dr Anton Sokolov

(anton.sokolov@physics.ox.ac.uk)

Title: Astrophysical probes of dual axion-photon coupling

Abstract:
Hypothetical particles called axions are one of the most popular candidates for the role of the cold dark matter, moreover axions can explain the absence of the electric dipole moment of the neutron. Possible electromagnetic signatures of axions are actively searched for in laboratory experiments and astrophysical observations. Recently, a new form of axion electrodynamics was proposed which evades many of the existing experimental searches. The goal is to study the implications of this new form of axion electrodynamics for astrophysical observations, and possibly predict novel axion signals from stars.

Prerequisites:
Electrodynamics and Field Theory, Basics of Astrophysics.

Reading:
G. Raffelt, "Stars as Laboratories for Fundamental Physics", 2) A. Caputo and G. Raffelt, "Astrophysical Axion Bounds: The 2024 Edition".

Supervisor: Prof Ard Louis

(ard.louis@physics.ox.ac.uk)

Title: Biological Evolution and a Bias towards Simplicity?

Abstract:
Evolution proceeds by mutations to genotypes that in turn change phenotypes (the organism). But since the number of genotypes is much larger than the number of phenotypes, concepts of genetic entropy must enter into the equations, which means methods from statistical mechanics become relevant. In this project you will study some recent advances that use algorithmic information theory to argue for a bias towards simplicity in biology. See, for example, the papers below:
Symmetry and simplicity spontaneously emerge from the algorithmic nature of evolution, Iain G Johnston, Kamaludin Dingle, Sam F. Greenbury, Chico Q. Camargo, Jonathan P. K. Doye, Sebastian E. Ahnert, Ard A. Louis PNAS 119, e2113883119 (2022).
Bias in the arrival of variation can dominate over natural selection in Richard Dawkins' biomorphs View ORCID Profile, Nora S. Martin, Chico Q. Camargo, Ard A. Louis doi: https://doi.org/10.1101/2023.05.24.542053

Title: Sloppy Systems

Abstract:
Many models in biology, engineering and physics have a very large number of parameters. Often many of these are only known approximately. Moreover, in John von Neuman's famous quip "with four parameters I can fit an elephant, and with five I can make him wiggle his trunk." suggests that only a small set of these parameters are actually relevant? Could there be a fundamental theory of these complex systems that allows us to work out what the key parameters are?

References:

1. Transtrum, Mark K., Machta Benjamin, Brown Kevin, Daniels Bryan C., Myers Christopher R., and Sethna James P. , Perspective: Sloppiness and Emergent Theories in Physics, Biology, and Beyond, J. Chem. Phys., Volume 143, Issue 1, (2015)
2. Machta, Benjamin B., Chachra Ricky, Transtrum Mark K., and Sethna James P. , Parameter Space Compression Underlies Emergent Theories and Predictive Models, Science, Volume 342, p.604-607, (2013)
3. Gutenkunst, R. N., Waterfall J. J., Casey F. P., Brown K. S., Myers C. R., and Sethna J. P., Universally sloppy parameter sensitivities in systems biology models, PLoS Computational Biology, Volume 3, p.1871-1878, (2007)
4. Waterfall, J. J., Casey F. P., Gutenkunst R. N., Brown K. S., Myers C. R., Brouwer P. W., Elser V., and Sethna J. P. , Sloppy-model universality class and the Vandermonde matrix, Physical Review Letters, Volume 97, p.150601, (2006)

Title: Theory of Deep Learning

Abstract:
Deep neural networks (DNNs) have revolutionised machine learning. In spite of their great success, many questions remain about why they work so well. One key issue is why they generalise so well in the overparameterised regime, where classical learning theory predicts that they should heavily overfit. We have recently used concepts from Algorithmic Information Theory (AIT) to argue that that DNNs are exponentially biased towards functions with low Kolmogorov complexity. If this inductive bias reflects patterns seen in nature, then this may explain the conundrum of good generalisation in the overparameterised regime. But many questions remain, and in this project you would use a combination of theory and simulations to peer into the DNN black box, and to hopefully understand what makes them so special.

See http://www.physicsmeetsml.org/posts/sem 2020 06 03/ for some more background.

Title: Effects of Mass Vaccination on the Dynamics of SIRS Systems with Seasonal Variation in Transmissibility

Abstract:
For many pathogens, infection-blocking immunity is transient even though immunity against severe disease (whether acquired through natural infection or vaccination) may be lifelong. The interplay between seasonal changes in HIT and loss of infection blocking immunity is therefore a critical determinant of dynamics of pandemic spread and of the characteristics of endemic equilibrium of any emerging pathogen. This project will focus on:
i. how the time of arrival of the pathogen within the seasonal cycle of transmissibility affects the initial dynamics of infection and subsequent establishment of an endemic equilibrium;
ii. how these dynamics are affected by pre-existing immunity (for example, due to exposure to related pathogens);
iii. how mass vaccination can alter these dynamics.
We will refer to available data on SARS-CoV-2 in various settings to test and refine the hypotheses generated by these exercises.

Supervisor: Dr Christopher Couzens

(couzens@maths.ox.ac.uk)

Title: Equivariant Localization and supergravity

Abstract: Equivariant localisation is a powerful mathematical result which allows for the evaluation of integrals on a space with a symmetry using topological data of the space. It has recently been used in supergravity to compute various observables such as the on-shell action and anomalies. This thesis will review this recent topic before applying it to a new setup.

Pre-requisites: The topic uses Riemannian geometry and supersymmetry/supergravity. The student should be familiar with the basics of Riemannian geometry (metric, curvature, forms) or taking the GR1 C7.5 course and/or the Differentiable manifolds (C3.3) course. Supersymmetry and Supergravity will be learnt as a byproduct of the dissertation.

Title: Classifying supersymmetric solutions in supergravity

Abstract: Finding solutions to the Einstein equations is very difficult, they are second order non-linear equations. One method for finding solutions is to impose additional symmetries, one such symmetry is supersymmetry. Imposing that the solution preserves supersymmetry typically allows us to replace the second order PDEs with first order PDEs. We will review how this is done using G-structures and Generalised complex geometry before applying this to a new class of solutions.

Pre-requisites: The topic uses Riemannian geometry and supersymmetry/supergravity. The student should be familiar with the basics of Riemannian geometry (metric, curvature, forms) or taking the GR1 (C7.5) course and/or the Differentiable manifolds (C3.3) course. Supersymmetry and Supergravity will be learnt as a byproduct of the dissertation.

Supervisor: Prof Ed Hardy

(edward.hardy@physics.ox.ac.uk)

Title: The Strong CP Problem and Axioms

Abstract:
One of the outstanding mysteries of the Standard Model of particle physics is the absence of CP violation in the strong sector. This project involves first reviewing the origin of CP violation in gauge theories, which has a fascinating connection to non-perturbative dynamics. Possible solutions to the strong CP problem will also be studied. A two-unit project could extend to analysing a recent paper that claims (possibly erroneously) that there is in fact no strong CP problem.

References:
Advanced Topics in Quantum Field Theory, Shifman (widely available in libraries)
https://inspirehep.net/literature/1707528

Title: Hamiltonian Truncation and Machine Learning

Abstract: Hamiltonian truncation is an approach to analysing quantum field theories in the strongly coupled regime, in which the full Hilbert space of the theory is truncated and the resulting system is studied numerically. This project will involve reviewing the existing literature and attempting to exploit machine learning techniques to obtain an optimized truncated subspace.

Reading:
https://inspirehep.net/literature/1333856

Supervisor: Prof Fabian Essler

(fabian.essler@physics.ox.ac.uk)

Title: Heating rates in Floquet circuits

Abstract: In recent years there has been a lot of interest in simulating interacting many-particle quantum systems using superconducting circuits. Brickwall circuits naturally give rise to periodically driven ("Floquet") circuits. These are known to heat under time evolution [1,2] und approach an infinite temperature (completely mixed) state at late times. Circuits that have a globally conserved charge are then expected to exhibit hydrodynamic behaviour. In order to study the latter using numerical methods it is necessary to have a circuit that heats fast, so that the accessible time scales suffice to detect it. The objective of the project is to investigate a simple class of two-Qbit brick wall circuits with a single conserved charge, and use the diagnostic proposed in [3] to find which circuits heat fastest.

Reading list:

[1] A. Lazarides, A. Das and R. Moessner, Phys. Rev. E90, 012110 (2014).
[2] L. D'Alessio and M. Rigol, Phys. Rev. X 4, 041048 (2014).
[3] A. Rakcheev and A.M. Lauchli, Phys. Rev. Research 4, 043174 (2022).

Supervisor: Dr Harini Desiraju and Prof Jon Keating

(harini.desiraju@maths.ox.ac.uk)

Title: Semi-classical limits of Selberg integrals

Abstract: Special functions play a central role in describing physical phenomena. Some examples you may have encountered are Gamma functions, and Euler beta functions, which appear in the description of partition functions in statistical mechanics or computation of Feynman integrals. This project will focus on the multi-dimensional analogue of the Euler beta function, known as the Selberg integral.

Selberg integrals appear across diverse fields such as combinatorics, conformal field theory, and random matrix theory to name a few. You may begin by exploring the role of the Selberg integral in either random matrix theory or conformal field theory, where these integrals are commonly parameterized by beta, a parameter that encodes the underlying symmetry class of the system. As a concrete question, you will study these integrals in the (semi-classical) regime beta-> infinity, which is expected to give rise to interesting sets of equations with rich geometry.

References:

1. Chapter 17, Random matrices by M.L Mehta (available in the library)

2. The importance of the Selberg integral (https://arxiv.org/abs/0710.3981)

3. Random Matrix Theory and ζ (1/2 + it) (https://link.springer.com/article/10.1007/s002200000261)

4. Conformal blocks as Dotsenko-Fateev Integral Discriminants (https://arxiv.org/abs/1001.0563)

Supervisor: Prof Jason Lotay

(lotay@maths.ox.ac.uk)

Title: Minimal surfaces, mean curvature flow and applications

Abstract: Minimal surfaces provide the mathematical description of soap films, locally minimizing their surface area, and thus are important from the point of view of physical sciences (including relations to black holes) as well as geometry and topology. The mean curvature flow is a geometric evolution equation which takes a surface and tries to make it minimal. Again, besides the applications of mean curvature flow to geometry and topology, it also has connections to image processing, and the (inverse) mean curvature flow is used to prove the Penrose inequality inspired by the study of gravity. The aim of this project will be to look at some of the recent developments in theory of minimal surfaces and mean curvature flow of surfaces, using geometry, topology and analysis, as well as applications within or outside mathematics, such as in theoretical physics.

Prerequisites: Essential: Basic geometry (e.g. material equivalent to B3.2 Geometry of surfaces) and basic topology (e.g. material equivalent to A5 Topology); Recommended: It would be good to learn alongside this dissertation the following topics - Differentiable Manifolds (C3.3), Riemannian Geometry (C3.11); Useful: Again, alongside this dissertation it might be helpful to learn Partial Differential Equations (e.g. C4.3).

Reading list:
T. Colding and W. Minicozzi, A Course in Minimal Surfaces, 2011
C. Mantegazza, Lecture Notes on Mean Curvature Flow, 2012

Supervisor: Prof Joseph Conlon

(jospeh.conlon@physics.ox.ac.uk)

Title: Cosmic Strings

Abstract: Cosmic strings are extended 1-dimensional topological defects that have long been considered a possible element of the universe. Such strings can arise either in field theory through symmetry breaking phase transitions or as fundamental cosmic superstrings. Although cosmic strings were originally considered as a candidate for structure formation in the universe, this possibility did not survive contact with data on large-scale structure and the distribution of galaxies. However, low-tension cosmic string networks still exist as a possibility and are a speculative explanation for the origin of the ultra-low frequency gravitational waves recently observed by pulsar timing arrays. The dissertation will review the physics of cosmic strings and explore some aspect of their physics in more depth. It can be offered as either a 1- or 2-unit dissertation.

Pre-requisites: While no course is an absolute pre-requisite, a familiarity with field theory and cosmology would be very helpful.

Reading list:

As starter references,

Cosmic Strings and Other Topological Defects, (Vilenkin + Shellard, CUP, 2000)
Cosmic Strings and Superstrings, E. Copeland and T. Kibble, arXiv:0911.1345

These should then be used as a base from which to explore the literature.

Supervisor: Prof Julia Yeomans

(julia.yeomans@physics.ox.ac.uk)

Title: Active Matter

Abstract:
Active systems take energy from their surroundings on a single particle level and use it to do work. This means that they naturally operate out of thermodynamic equilibrium and provide examples of non-equilibrium statistical physics. Dense active matter has many surprising properties such as active turbulence and motile topological defects, motility induced phase separation, odd viscosities and the breakdown of detailed balance. The dissertation will probe more deeply into an aspect of active materials; possible examples are spontaneous flow in confined active systems, swimming at low Reynolds number, active wetting or forces in confluent cell layers.

Reading:
G Gompper et al, The 2020 motile active matter roadmap, J. Phys.: Condens. Matter 32 193001
(lots of short articles introducing active matter)
A. Doostmohammadi, J. Ignés-Mullol, J.M. Yeomans, and F. Sagués, Active nematics. Nat. Commun. 9, 3246 (2018) (for a review of active nematics)

Supervisor: Prof Lionel Mason

(lionel.mason@maths.ox.ac.uk)

Title: Twistor theory and applications

Abstract: Twistor theory is a geometrical framework for the formulation of physical theories introduced by Roger Penrose in the 1960s. It provides a more primitive geometry from which space-time itself emerges together with physical fields thereon using ideas from algebraic geometry and complex analysis. It traces its origins to the Klein correspondence from classical projective geometry in which the space of lines in three dimensional projective space form a four-dimensional quadric which in twistor theory is re-interpreted as Minkowski space-time. This framework has had many applications to mathematical physics over the years, any one of which might form the basis for a dissertation of one or two units.

1. The classification of integrable systems of nonlinear equations of Mathematical Physics and construction of exact solutions, see Mason \& Woodhouse, Integrability, Self-Duality and Twistor Theory, OUP Monograph, 1996. This could be reviewed in the light of recent Chern-Simons approaches due to Costello, Witten and Yamazaki, Gauge Theory and Integrability, ICCM Not. 06, arxiv:1709.09993.

2. Applications to the construction of scattering amplitudes and correlation functions for 4d gauge and gravity theories. A prerequisite is QFT and a general introduction to scattering amplitudes can be found in the CUP book by Elvang and Huang book available at https://arxiv.org/abs/1308.1697. From here one could study more recent developements such as ambitwistor strings and the scattering equations, Geyer and Mason The SAGEX Review: Ambitwistor strings and amplitudes from the worldsheet, J.Phys.A 55 2022, arxiv:2203.13017 or more recent applications to the construction of cosmological and AdS correlators A new twist on spinning (A)dS correlators https://arxiv.org/abs/2408.02727. Another approach is via twistor actions which more ambitiously connects to celestial holography, see Kmec, Mason, Ruzziconi and Sharma, S-algebra in Gauge Theory: Twistor, Spacetime and Holographic Perspectives, arxiv:2506.01888.

Supervisor: Dr Nick Jones

(nick.jones@maths.ox.ac.uk)

Title: Symmetry-resolved entanglement in quantum chains

Abstract:
Entanglement entropy (EE) is of fundamental importance to our understanding of ground states of quantum many-body systems. The aim of this dissertation is to review some recent developments in the area of symmetry-resolved EE - the EE of a particular symmetry sector of the ground state. Directions one can take include calculations in exactly-solvable lattice models, and numerical investigation of the ground states of different symmetric Hamiltonians.

Prerequisites:
Part B Further Quantum Theory (or equivalent)

Relevant courses:
Quantum Field Theory, Random Matrix Theory.

Reading:
P. Calabrese and J. Cardy 2009 J. Phys. A: Math. Theor.42 504005
M. Goldstein and E. Sela 2018 Phys. Rev. Lett. 120, 200602
R. Bonsignori, P. Ruggiero and P. Calabrese 2019 J. Phys. A: Math. Theor. 52 475302
S. Fraenkel and M. Goldstein J. Stat. Mech. (2020) 033106
N. G. Jones J. Stat. Phys., 188, 28 (2022)

Supervisor: Prof Renaud Lambiotte

(renaud.lambiotte@maths.ox.ac.uk)

Title: How Directed Are Directed Networks?

Abstract:
Many real-world networks are composed of directed edges that are not necessarily reciprocated. While several algorithms have been generalised to the case of directed networks, conceptual challenges, i.e. to quantify the level of hierarchy (and its impact on dynamics). In this project, we will investigate the notion of hierarchy in directed networks from different, possibly complementary viewpoints. The two main challenges will be to design embedding techniques allowing to rank nodes according to their importance, while grouping “similar nodes”, and to investigate how hierarchies impact on linear dynamics, more specifically via the non-normality of the coupling matrices.

Prerequisites:
Taking the course C5.4. Networks is recommended.

Reading list:
MacKay, Robert S., Samuel Johnson, and Benedict Sansom. "How directed is a directed network?" Royal Society open science 7.9 (2020): 201138.
Lambiotte, Renaud, and Michael T. Schaub. Modularity and Dynamics on Complex Networks. Cambridge University Press, 2021.

Title: Dynamics and structure of complex-weighted networks

Abstract: Complex numbers define the relationship between entities in many situations. A canonical example would be the off-diagonal terms in a Hamiltonian matrix in quantum physics. Recent years have seen an increasing interest to extend the tools of network science when the weight of edges are complex numbers. The purpose of this project will be to explore further the structure and dynamics of such complex-weighted networks. We will consider linear processes such as consensus dynamics and random walks, from which build algorithms to extract information from the systems. Relatedly, the student may consider problems where edges are equipped by linear transformation, thus going beyond rotations in two dimensions.

Reading list:

Tian, Yu, and Renaud Lambiotte. "Structural balance and random walks on complex networks with complex weights." SIAM Journal on Mathematics of Data Science 6.2 (2024): 372-399.

Tian, Yu, et al. "Matrix-weighted networks for modeling multidimensional dynamics." arXiv preprint arXiv:2410.05188 (2024).

Supervisor: Dr Seyed Faroogh Moosavian

(faroogh.moosavian@maths.ox.ac.uk)

Title: Quantum Theory of Gravity

Abstract: Quantum gravity has remained elusive for nearly a century, dating back to the earliest attempts by Pauli, Heisenberg, Rosenfeld, Bronstein, and others in the 1930s. Despite numerous efforts on many fronts, this arguably most profound challenge at the foundation of theoretical and mathematical physics has not yet yielded. In fact, it is fair to say that all existing approaches have not even managed bending this very thick rod, let alone cracking it [1, 2].

This project aims to delve into one of the most important series of papers in the history of the subject: the trilogy Quantum Theory of Gravity I, II, and III by Bryce DeWitt, a (if not the) principal architect of modern research in the field [3, 4, 5]. These papers encompass the canonical and covariant approaches to the quantization of gravitational interactions, applications of these methods, the derivation of the famous Wheeler–DeWitt equation, the problem of time, the many-worlds interpretation of quantum mechanics, the principal challenges that remain in completing the program, and much more.

Among DeWitt's many contributions, which can be read about in [6], two stand out for their foundational importance in quantum field theory and quantum gravity alike: the de¬velopment of the background-field method, and the systematic formulation of gauge-fixing in the path integral formalism. The background-field method allows one to maintain man¬ifest gauge (and diffeomorphism) invariance while quantizing fluctuations around a fixed classical background–crucial for any sensible approach to perturbative quantum gravity. Closely related, DeWitt's elegant and general approach to gauge fixing—via what would become known as the Faddeev–Popov procedure–originates from the very ideas developed in these papers.

Unlike most modern literature on the subject, this series is highly technical: there are no random or vague assumptions made to simplify or obscure the main challenges. The attempt is to build everything for the quantization of gravity in four spacetime dimensions from scratch. As such, the project is correspondingly demanding–certainly not for the faint of heart.

Anyone interested is strongly encouraged to browse the papers in advance to get a sense of their scope and depth. If you remain interested after that, please contact me for further discussion.

For a Master's student, the goal will be to absorb as much as possible—not necessarily by reading the entire trilogy, but by seriously engaging with its core ideas and reflecting on potential questions that might be addressed using these methods.

The dissertation should include:

1. A detailed review of one of the main topics or methods from the trilogy;
2. An exploration of one question that can be pursued using that reviewed topic or method—this could either be a question that has already appeared in the literature, or, if the student is ambitious, something entirely new.

The choice in (2) depends on whether the student would like to complete a one-unit or two-unit dissertation.

Please Notice: If your main goal is to perform quick computations, publish a paper immediately, or engage with the latest hot and mainstream developments, then this project may not align with your interests. Its purpose is to build a strong and lasting foundation in the subject, one that you can draw upon in your future studies, if you are inclined to pursue it further. For clarity, there is no supersymmetric content in this project.

Reading list:

[1] R. P. Feynman, F. B. Morinigo, W. G. Wagner, B. Hatfield, J. Preskill and K. S. Thorne, Feynman Lectures on Gravitation. Addison–Wesley, Jun, 1995. 1

[2] R. P. Woodard, How Far Are We from the Quantum Theory of Gravity?, Rept. Prog. Phys. 72 (Jul, 2009) 126002, [0907.4238]. 1

[3] B. S. DeWitt, Quantum Theory of Gravity. I. The Canonical Theory, Phys. Rev. 160 (Aug, 1967) 1113–1148. 1

[4] B. S. DeWitt, Quantum Theory of Gravity. II. The Manifestly Covariant Theory, Phys. Rev. 162 (Oct, 1967) 1195–1239. 1

[5] B. S. DeWitt, Quantum Theory of Gravity. III. Applications of the Covariant Theory, Phys. Rev. 162 (Oct, 1967) 1239–1256. 1

[6] S. M. Christensen, ed., Quantum Theory of Gravity, Essays in Honor of the 60th Birthday of Bryce C DeWitt. CRC Press, 1984. 1

Supervisor: Dr Thomas Spieksma

(thomas.spieksma@physics.ox.ac.uk)

Title: Interactions of black holes crossing through active galactic nuclei

Abstract: Extreme-mass-ratio inspirals (EMRIs) are expected to be key sources for the future space-based gravitational-wave observatory LISA, yet their formation channels are poorly understood. One promising scenario involves stellar-mass black holes being captured by active galactic nuclei (AGN). These captures occur at large distances from the central black hole, and their subsequent evolution must be modelled to predict when and how they enter the LISA sensitivity band. In this project, the student will study the interaction of the captured black hole with the AGN, and determine the expected orbital parameters (such as inclination and eccentricity) by the time the system reaches the relativistic regime.

For relevant literature and further information, please contact Dr Spieksma directly.

F - Course Calendar

MICHAELMAS TERM	
0th week	Induction Class sign-up for Part C Maths open on Moodle
Week 1	Michaelmas term lectures begin Friday (17th October): Deadline to request approval for non-curriculum subject
Week 2	Part C Maths classes start Class sign-up for Physics classes open on TMS Friday (24th October): Deadline for MMathPhys students to request transfer back to their original degree programme (MMath/Mphys/MMathPhil)
Week 3	Thursday (30th October): Exam entry for Hilary exams open
Week 4	Dissertation application form open Thursday (6th November): Deadline to complete exam entry for Hilary exams Friday (7th November): Deadline to request exam adjustments in time for Hilary exams Deadline to change class times for both Maths (Moodle) and Physics (TMS)
Week 5	
Week 6	Monday (17th November): Deadline to apply for a dissertation
	Tuesday (18th November): Jobs for Mathematicians Fair, 4-6pm Mathematical Institute
Week 7	
Week 8	Approval for dissertations sent out
Christmas Vac	
HILARY TERM	
0th week	Exams Class sign-up for Part C and bespoke MTP Maths courses open on Moodle
Week 1	Hilary term lectures begin
	Thursday (22nd January): Exam entry for Michaelmas homework, Hilary submissions and Trinity exams open
Week 2	Class sign-up for Physics classes open on TMS
	Thursday (29th January): Deadline to complete exam entry for Michaelmas homework, Hilary submissions and Trinity exams
Week 3	
Week 4	Friday (13th February): Advanced Philosophy of Physics mini-project titles released Deadline to change class times for both Maths (Moodle) and Physics (TMS) Deadline to make new exam adjustments requests in time for Trinity exams
Week 5	Results of Hilary term exams released
Week 6	
Week 7	
Week 8	Friday (13th March): Mini-projects and take-home exam released

Easter Vac	Wednesday (18th March): Collisionless Plasma Physics take-home exam submission deadline Friday (3rd April): Galactic and Planetary dyanmics mini-project submission deadline Friday (17th April): C5.4 Networks mini-project submission deadline
TRINITY TERM	
0th week	Trinity exams Class sign-up for bespoke MTP Maths courses open on Moodle
Week 1	Trinity term lectures begin
Week 2	Class sign-up for Physics classes open on TMS
Week 3	
Week 4	Friday (22nd May): Adv. Phil. of Physics mini-project submission deadline Deadline to change class times for both Maths (Moodle) and Physics (TMS)
Week 5	
Week 6	Monday (1st June): Dissertation submission deadline
Week 7	Part C Maths and Physics exams and some bespoke MTP exams
Week 8	
Long Vac	The provisional date for the Final Exam Board meeting is 17th July. Your college must submit an MCE by noon the previous day if you wish it to be considered by the Examiners at the meeting. Your college may submit an MCE up to 1 month after the Final Exam Board meeting. It will be at the Proctors' discretion whether or not they forward it to the Examiners for consideration.
	Final exam results and classifications will be released towards the end of July. DO NOT BOOK A GRADUATION CEREMONY UNTIL YOU HAVE RECEIVED YOUR EXAM RESULTS