Oxford Master's Course
in
Mathematical and Theoretical Physics

Master of Mathematics and Physics (MMathPhys) and MSc in Mathematical and Theoretical Physics

Course Handbook

2024-2025

This handbook applies to students starting the Master of Mathematics and Physics (MMathPhys) or the MSc in Mathematical and Theoretical Physics in Michaelmas term 2024. 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.
If you have any concerns please contact
mathematical.physics@maths.ox.ac.uk.

The information in this handbook is accurate as of 28 October 2024, however it may be necessary for changes to be made in certain circumstances, as explained at **www.ox.ac.uk/coursechanges**. 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.

Version 3.1

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 Lionel Mason and Prof Caroline Terquem

Contents

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 below, together with a list of key contacts.

1.1 Key Sources of Information

Course website: http://mmathphys.physics.ox.ac.uk/
The course schedule, course synopses, details of seminars and the online course handbook can all be found here.

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.

Seminars: http://mmathphys.physics.ox.ac.uk/seminars

Oxford student website: http://www.ox.ac.uk/students
This website provides access to information, services and resources.

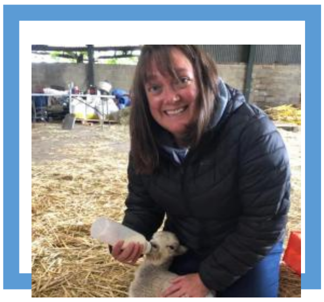
Oxford Student Handbook: https://www.ox.ac.uk/students/academic/student-handbook
This contains general information and guidance about studying at the University of Oxford, and gives you formal notification and explanation of the University's codes, regulations, policies and procedures.

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

1.2 Key contacts

Course Director
Prof Lionel Mason
Email: lmason@math.ox.ak

Chair of JSC
Prof Caroline Terquem
Email: caroline.terquem@physics.ox.ac.uk



Head of Academic Administration
Charlotte Turner-Smith
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Graduate Studies Officer
Pip Beck
Email: mathematical.physics@maths.ox.ac.uk

MSc Administrator
Eleanor Kowol
Email: mathematical.physics@maths.ox.ac.uk

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

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

1.3 The Academic Year

The course lasts three terms, from the beginning of October to the end of the following June. Some work is carried out in the vacations.

For the academic year 2024–2025, the course begins with an induction on 8 October 2024. The dates of the University Full Terms for the Academic Year 2024–2025 are:

MT = Michaelmas Term 2024	**13 October – 7 December**
HT = Hilary Term 2025	**19 January – 15 March**
TT = Trinity Term 2025	**27 April – 21 June**

A calendar of important dates is given in Appendix A.

1.4 Finding Your Way Around

Teaching for the course (where in-person teaching occurs) will take place in the Mathematical Institute (**http://www.maths.ox.ac.uk/about-us/travel-maps**) 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#collapse1426661

The main entrance to the Clarendon Laboratory is on Parks Road, next to the University Parks:

https://www.accessguide.ox.ac.uk/clarendon-laboratory#collapse2861361

At the Mathematical Institute, all lecture rooms and classrooms are located on the mezzanine level.

A searchable, interactive map of all college, department and libraries can be found at **https://maps.ox.ac.uk/bd821e30-d8ba-11eb-a363-059e537832a1**.

2 The MSc Course

2.1 Overview

The Master's Course in Mathematical and Theoretical Physics is offered in two modes, the MMathPhys for Oxford students 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 2008) and Mathematics, Statistics & Operational Research (QAA 2015).

2.2 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.

2.3 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 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.

2.4 Course Structure

The programme consists of a large array of lecture courses covering the main areas of modern Theoretical/Mathematical Physics and Applied Mathematics. The courses are subdivided into the following *strands:*

- **Quantum Field Theory, Particle Physics and String Theory**
- **Theoretical Condensed Matter Physics,**
- **Theoretical Astrophysics, Plasma Physics and Physics of Continuous Media.**
- **Mathematical Foundations of Theoretical Physics**

Various areas of Theoretical and Mathematical Physics are interconnected, grounded in universal principles and thrive on ideas that cross many sub-field boundaries. A number of courses are shared between the three strands and emphasise the unity of the subject. This applies especially to the *foundational courses* offered in Michaelmas term. These are followed by increasingly specialised courses in Hilary and Trinity terms, although those too will strive to make connections between subject areas.

There are no compulsory courses and you will thus be able to choose a path reflecting your intellectual tastes or career choices; Appendix B gives examples of different pathways through the course. An overview of the courses can be found in the table accompanying this section. Detailed synopses for each course can be found at https://mmathphys.physics.ox.ac.uk/course-schedule and a table providing details of the assessment method for each course can be found in Appendix A of the examination conventions.

You will be required to undertake 10 units, with 1 unit corresponding to 16 hours of lectures. This means that 16-hour lecture courses count as one unit, while, for example, 24-hour lecture courses count as 1.5 units. More specifically you are required to offer:

(a) **four units that are assessed by written invigilated exams,**

(b) **a further three units that are assessed by written invigilated exams or by other formal assessments,**

(c) **three other units (which may be from courses with homework completion requirement only or from assessed courses).**

One or two of the 10 units in (b) or (c) can be replaced by a dissertation. There are no other formal constraints on course choices and students are otherwise free to design their own pathways (although paying close attention to the guidance offered is strongly recommended). Note however that you should be careful about the number of units you undertake each term, and that taking too many units in Trinity term may be difficult as exams start in week 6. In practice it may be difficult to fit in more than 12 units in total. **Please note that 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 Appendix A of the exam conventions.

You will be offered detailed academic guidance from the Director of Studies or an Academic Adviser designated by the Director of Studies on choosing an individual path suitable for you. Course lecturers will also advise on the recommended background for their courses or possible follow-up courses you might wish to choose.

2.5 Additional Courses

In addition to the courses listed in the table, which are offered explicitly as part of the MMathPhys/MSc programme, you may be allowed to choose a maximum of three units worth of MMath Part C: https://www.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning or MPhys Part C: https://www3.physics.ox.ac.uk/lectures/ lecture courses that are not listed here, subject to approval by the Director of Studies, Prof Lionel Mason. To request approval for this, you must contact Professor Mason at lmason@maths.ox.ac.uk, copying in mathematical.physics@maths.ox.ac.uk. Once Prof Mason has granted approval, your request will then be passed on by the administration to the Director of Undergraduate Studies who will provide the final approval, depending on whether there are spaces in the associated Part C Maths classes for the approved subjects you applied for. For Physics Part C approved subjects that have been granted this approval, please e-mail mathematical.physics@maths.ox.ac.uk and your request will be passed on to the relevant colleagues at Physics. Approval for MT additional courses should be sought by Monday week 1 of MT. Approval for HT additional courses should be sought by week 9 of MT. If you stated any preferences for approved subjects on your initial course registration form in September, these will be handled by the administration and you do not need to make the request again.

Legend for fonts, colours and superscripts in the Table:

Bold: a foundational course;

Red*(P U:NN)*: a course also taught (in some cases in part) as a Part C course in Physics, NN is its number;

Blue*(MU:NNN)*: a course also taught as a Part B or C course in Mathematics, NNN is its number;

Purple: an MMathPhys/MSc course, also taught as a PG course in Mathematics;

Black: an MMathPhys/MSc course, also taught as a PG course in Physics;

'M' a course where lectures and classes are taught at the Mathematical Institute;

'P' a course where lectures and classes are taught at the Department of Physics;

'Phil' a course where lectures and classes are taught at the Department of Philosophy;

(∗) a course that may not be available every year.

Overview of Lecture Courses			
	Theoretical Particle Physics	*Theoretical Condensed Matter Physics*	*Theoretical Astrophysics, Plasma Physics & Physics of Continuous Media*
MT	**Quantum Field Theory** (P) (24)		
		Field Theories and Collective Phenomena in Condensed Matter (P U:C6) (P) (24)	
		Kinetic Theory (P) (28)	
		Anyons & Topological Quantum Field Theory (P) (16)	Quantum Processes in Hot Plasma (P) (12)
	General Relativity I (MU:C7.5) (M) (16)		**General Relativity** I (MU:C7.5) (M)
	Perturbation Methods (MU:C5.5) **(M) (16)**		
	Numerical Linear Algebra (MU:C6.1) (M) (16)		
	Groups and Representations (P) (24)		
	Algebraic Topology (MU:C3.1) (M) (16)		
	Differentiable Manifolds (MU:C3.3) (M) (16)		Differentiable Manifolds (MU:C3.3)
	Advanced Philosophy of Physics (Phil.) (24)		
	Algebraic Geometry (MU:C3.4) (M) (16)		
HT		Advanced Fluid Dynamics (P) (16)	
	Riemannian Geometry (MU:C3.11) (M) (16)	**Nonequilibrium Statistical Physics** (P) (16)	
	Advanced QFT (P) (24)	Quantum Matter (P) (16)	High Energy Density Physics (P)
	String Theory I (M) (16)		Collisionless Plasma Physics (P) (18)
	Supersymmetry & Supergravity (M) (16)		Geophysical Fluid Dynamics (P) (16)
	Intro to Quantum Information (MU:C7.4) (M) (16)		
	Low-Dimensional Topology & Knot Theory (MU:C3.12) (M) (16)		
	General Relativity II (MU:C7.6) (M) (16)		General Relativity II (MU:C7.6) (M)
		Algorithms and Computations in Theoretical Physics	
	Lie Groups (MU:C3.5) (M) (16)	Networks (MU:C5.4) (M) (16)	
	Cosmology (P) (16)		Cosmology (P) (16)
	Random Matrix Theory (MU:C7.7) (M) (16)		
	Applied Complex Variables (MU:C5.6) (M) (16)		
	Advanced Philosophy of Physics (Phil.) (24)		
	Geometric Group Theory . (MU:C3.2) (M) (16)		Galactic & Planetary Dynamics.
TT	Conformal Field Theory (M) (16)		
	String Theory II (*) (M) (16)		Geophysical Fluid Dynamics (P)
	The Standard Model and Beyond I (P) (16)		
	The Standard Model and Beyond II (P) (16)		
	Quantum Field Theory in Curved Space (M) (16)	Topics in Soft & Active Matter Physics (P) (8)	
		An Introduction to Topological Phases of Matter	
		Disorder in Condensed Matter	Astroparticle Physics
	Machine Learning Fundamentals with Applications to Physics and Mathematics		
			Collisional Plasma Physics (P)
			Advanced Topics in Plasma
	Renormalisation Group (P) (16)		
	Dissertation, replacing one or two 16-hour lecture course		

3 Teaching and Learning

3.1 Organisation of Teaching

Teaching for the course will be provided jointly by the Department of Physics and the Mathematical Institute through lectures and classes. In addition, students undertaking a dissertation will have supervision meetings with their dissertation supervisor.

3.2 Lectures

Depending on the options you take you will have between 6-8 hours of lectures per week. Where in-person lecturing occurs, a lecture timetable for each term will be made available on the course website **https://mmathphys.physics.ox.ac.uk/course-schedule**. For online teaching, you will be sent a document providing links to access recorded lectures or to access live-streamed lectures. Please do not share these links outside your cohort. If you have a friend on another Maths/Physics related degree at the University of Oxford who would like to access lecture links, please direct them to either the course lecturer or mmathphys@physics.ox.ac.uk and one of us will be able to determine if the student can be given access.

Course Material

Course material, such as lecture notes and problem sheets, will be published on the Mathematical Institute's course website at courses.maths.ox.ac.uk, and the Department of Physics' website. Students should follow the links to the appropriate pages from the lecture schedule on the course website.

3.3 Class Registration

Lecture courses will normally be accompanied by problem sets and weekly or fortnightly problem classes. Classes will usually contain 8–10 students. For most courses you will need to sign-up for the set of classes you wish to attend at the start of each term, and this is usually done via an online sign-up system.

For classes held at the Mathematical Institute, you will be sent an email in week 0 from the e-mail address mathematical.physics@maths.ox.ac.uk alerting you that class registration is open and providing you with details of the registration process. You will not be able attend classes unless you register for them beforehand. You will be able to enroll in classes and then view which classes you have successfully signed up to via courses.maths.ox.ac.uk.

For classes held in the Physics Department, registration will be via Teaching Management System (TMS). You will be sent an email from the e-mail address mathematical.physics@maths.ox.ac.uk alerting you that class registration is open.

To see which courses take place in each department, please refer to the table page 6 of the course handbook, where a course followed by a (P) is a course held at the Department of Physics, and a course followed by an (M) is a course held at the Mathematical Institute.

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.

3.4 Class Withdrawal

For classes held at the Mathematical Institute and at the Department of Physics, please note that after being assigned to a class, you will have until Monday week 4 of each term to request a class switch or to decide that you would no longer like to attend a particular class. 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.

3.5 Online Submission Process

Whether you are taking a course which is assessed by homework completion, or are submitting problem sheets in general for an examined or formally assessed course, you will be required to submit your homework online by the times and dates which will be made available on the course pages once these have been confirmed by the lecturers and teaching assistants. If you are submitting problem sheets for a Physics course, you will submit via Canvas. If you are submitting problem sheets for a Maths course, you will submit via Moodle.
https://canvas.ox.ac.uk/courses/276069
https://courses.maths.ox.ac.uk/course/index.php?categoryid=148
Ensure your name and college e-mail address is on your work, but NOT your candidate number. This is because the candidate number is meant to make you anonymous, but in the instance of homework, your teaching assistant needs to know your name so they can return your work to you. If you reveal your candidate number along with your name, you are no longer anonymous.
Include your name in the name of the PDF of homework you submit. Write the name of the lecture course and problem sheet at the top of your work; e.g. Groups and Representations Problem Sheet 1.
Please note that it is your responsibility to ensure that your work has been submitted, especially if you are submitting homework for the purpose of assessment by homework completion. If you are concerned that your internet connection may have been interrupted and your work did not submit, you should contact your Teaching Assistant as soon as possible to confirm it has been received.

3.6 Dissertations

You may opt to offer a dissertation as one or two of your ten units. A dissertation offers a substantial opportunity for independent study and research, and would be undertaken under the guidance of a member of the Department of Physics or the Mathematical Institute. A dissertation involves investigating and then presenting in writing a particular area of Mathematical Physics or Theoretical Physics; you would not be required to (but may) obtain original results. A list of possible dissertation topics is given in Appendix C but you are not limited to this list and may propose your own topic instead.

The exact process to apply for a dissertation can be found via the Dissertation Guidance document here. The link also includes a LaTeX template you can use for formatting your dissertation, and guidance on finding a supervisor.

You can view past students' dissertations via the following link: **https://www.maths.ox.ac.uk/members/students/undergraduate-courses/mmathphys-msc-mtp/past-dissertations.** You will need to log in via the top right corner using your Single Sign On (SSO).

You should plan on beginning work on your dissertation soon after your abstract has been approved. You are advised to bear in mind that you will need to use your time in the Easter vacation and early Trinity term wisely to balance preparing for the Trinity term exams, working on your dissertation, and completing work for other courses you may be taking.

Your supervisor will read and provide feedback on the initial draft of your dissertation (provided that it is submitted to them in good time!).

The submitted dissertation must conform to the following points.

- The dissertation must include an abstract and a bibliography.
- The dissertation must be word-processed and have a font size of 12pt.
- The text must be double spaced
- The dissertation must have a title page which includes the following:
  - the title of dissertation,
  - the candidate's examination number,
  - the title of the candidate's degree course,
  - the term and year of submission.
- Its length must not exceed 30 pages for a single unit and 60 pages for a double unit. The Examiners will not be obliged to read any work exceeding this page limit. The page count may exclude any table of contents, diagrams, tables, bibliography, dedications/acknowledgements, abstract and the texts of computer programs. However, any footnotes and appendices must be included.

3.7 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.

3.8 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.

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.

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

3.9 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)

4 Examinations and Assessments

4.1 Assessment of the Course

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 requirement. Each unit will be assessed by the method most suited to the material being taught. The table in the examination conventions indicates which courses are assessed and by which method and it indicates which courses have a homework completion requirement. The examinations are governed by the University's Examination Regulations and the course examination conventions.

4.2 Examination 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, resits and penalties for late submission. The examination conventions for 2024–25 can be found on the course website at **http://mmathphys.physics. ox.ac.uk/**.

4.3 Examination Entries

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 or this course there will be three examination entry dates:

7th November, week 4, Michaelmas term for courses examined by invigilated written examination in Hilary term;

30th January, week 2, Hilary term for Michaelmas Term practicals (homework) Hilary term submissions (such as mini-projects released in Hilary Term) and all courses assessed by invigilated written examination in Trinity term.

15th May, week 3, Trinity term for Hilary and Trinity term practicals (homework) and Trinity term submissions (such as the dissertation).

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, having made your entries, you subsequently change your mind about which courses to be assessed on, it is sometimes possible to make changes to your entry. This is only possible where the deadlines for both the option you wish to switch from and the option you wish to switch to remain in the future. Where this is the case, you must apply for permission in writing through your Senior Tutor or other college officer using the change of options form available from your College Office. You will be charged a fee for making a late change to your examination entry.

If you have entered for assessments in additional courses (beyond the required ten units) but subsequently decide not to take the additional assessments, then you should inform your College Office. You must do this prior to either the examination date for written examinations or the submission date for coursework. In cases where a course has two required methods of assessment, you must withdraw from the overall course before the first element of assessment is complete – i.e. where a course requires homework completion followed by a written exam, any student wishing to withdraw from the examination must do so before the final homework completion submission deadline.

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.

4.4 Examination Dates and Submission Deadlines

The calendar of important dates (Appendix A) gives the expected start dates for the invigilated written examinations and coursework submission deadlines. The examination timetable for invigilated written examinations will be set by the Examination Schools and published online at: **http://www.ox.ac.uk/students/academic/exams/timetables**.

4.5 Preparation and Submission of Coursework

4.5.1 Mini-Projects and Take-Home Examinations

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.

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 (see section 5 in the examination conventions). Please see the examination conventions and the Oxford students website (**http://www.ox.ac.uk/students/academic/exams/submission**) for advice on what to do if you are unable to submit your work on time due to medical emergency or other urgent cause.

4.5.2 Dissertation

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. Please note the information in section 4.5.1 regarding the importance of submitting your work on time.

4.5.3 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 for further information.

4.6 Sitting Invigilated Written Examinations

Information on (a) the standards of conduct expected in examinations and (b) what to do if you would like examiners to be aware of any factors that may have affected your performance before or during an examination (such as illness, accident or bereavement) are available on the Oxford Student website (**http://www.ox.ac.uk/students/academic/exams**) and in Section 8.2 of the examination conventions.

4.7 Examination 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.

4.8 Key Assessment Links

Dissertation Guidance: **http://mmathphys.physics.ox.ac.uk/students**

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

Examination Timetables: **http://www.ox.ac.uk/students/academic/exams/timetables**

Online Submission for Dissertations, Mini-Projects and Take-Home Exams:
https://oxford.inspera.com/

Online Submission for Problem Sheets: **https://courses.maths.ox.ac.uk/** and
https://canvas.ox.ac.uk/courses/276069

Past examination papers: https://mmathphys.physics.ox.ac.uk/past-examination-papers

Past examiners reports: http://mmathphys.physics.ox.ac.uk/students

5 Resources and Facilities

5.1 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 08.30–16.15.

5.2 Libraries

College Library

The main source of borrowed books is your own College library.

Radcliffe Science Library (RSL)

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

The Radcliffe Science Library is the science Library of the Bodleian and includes mathematics books at graduate and research level. Your University card will provide access.

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

Whitehead Library

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

5.3 Computing Facilities

Information regarding the University's IT Services can be found at **http://www.it.ox.ac.uk/**.

IT and Email accounts

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**

You will have access to various licenses; for further details go to **http://www.maths.ox.ac.uk/members/it/software-personal-machines**.

5.3 Careers and Employability

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 can be found at https://www.maths.ox.ac.uk/study-here/postgraduate-study
and at https://www.physics.ox.ac.uk/study/postgraduates for opportunities in the Department of Physics.

6 Student Representation and Feedback

6.1 Student Representation

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.

6.2 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.

6.3 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.

6.4 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.

6.5 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/**.

6.6 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

7 Student Support and Academic Policies

7.1 Where to Find Help

Generally speaking for graduate students, departments are the main source of academic support and colleges are the main source of pastoral support. For undergraduate students, colleges also play a key role in providing academic support.

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.

7.2 Illness

It is appreciated that most people will be ill occasionally during the course of the year and this should not adversely affect your studies. Since lectures will be recorded you should be able to catch up, provided you are not ill for long. If you will miss a class, it is appropriate to inform the class tutor who will make a note in the attendance log.

If you are ill on the day of a written examination, you should contact your college doctor or nurse who will be able to write a note for you to submit as part of a mitigating circumstances notice to examiners. If you are able to sit the examination then this note will be taken into account when your final result is decided. More details of how such a note will be used are given in the Examination Conventions.

If you are ill on the day of a written examination and unable to sit the examination then your college should apply to the Proctors on your behalf for you to be exempt from the examination — there will not be an opportunity to sit the examination at a later date.

If you are ill or suffer a bereavement in the time when you are revising or preparing work on a take-home examination or the dissertation, you should again approach your college and they can apply to the Proctors for an extension of the dissertation deadline or for your circumstances to be taken into account.

If illness or bereavement affects your ability to meet a problem sheet deadline for a homework completion course, it is possible to apply for an extended deadline for submission, or to be excused from that specific problem sheet. Applications should be made online at https://forms.office.com/e/Ka8efNgANC. Where the extended deadline requested falls before the class at which the work will be discussed, this will be sent to the lecturer for approval; where the extended deadline would fall after the class, or an excusal is requested, this will be sent to the Chair of Examiners for consideration.

If you are ill for a significant period of time during the year, you should discuss this with the Course Director as it may be appropriate for you to suspend your status to allow you to recover, then return to complete the course the following academic year.

7.3 Complaints and academic appeals within the Department of Physics and the Mathematical Institute

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**).

7.3 Buddy System

The Buddy System is an initiative to help our new MSc students integrate with current MMath/MPhys/ MPhysPhil students who are transferring to the MMathPhys for their final year. Once an MSc student's offer has become unconditional, they will be paired with a buddy from the same college, or a nearby college and will receive their buddy's college e-mail address. New students can seek advice from their MMathPhys buddy about aspects of student life which interest them such as exams, social events or courses.

7.4 Student 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/**.

7.5 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 Mareli Grady **mareli.grady@maths.ox.ac.uk** or James Munro **james.munro@maths.ox.ac.uk** if you have any questions or ideas you would like to discuss.

7.6 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**

Policy on Students Recording Lectures https://academic.admin.ox.ac.uk/educational-recordings-policy

7.7 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 at
http://www.maths.ox.ac.uk/members/building-information/security-safety-and-reporting-building-issues. In the case of evacuation of the lecture theatre give heed to the instructions of the lecturer.

7.8 Key Student Support Links and Contacts

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

Information on Disability and Accessibility: https://www.maths.ox.ac.uk/members/policies/disability
https://www.maths.ox.ac.uk/members/building-information/accessibility

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

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

Counselling Service: **https://www.ox.ac.uk/students/welfare/counselling** **(counselling@admin.ox.ac.uk)**

Departmental Harassment Advisors: a list can be found by clicking here

A Course Calendar

Michaelmas Term	
Tuesday 7th October, (week 0)	Induction
Monday 14th October (week 1)	Michaelmas term lectures begin
Thursday 7th November (week 4)	Examination entry for courses assessed by invigilated written examination in Hilary term
Friday 6th December (week 8)	Michaelmas term lectures end
Hilary Term	
Monday 13th January (week 0)	Provisional start date for HT invigilated examinations
Monday 20th January (week 1)	Hilary term lectures begin
Thursday 30th January (week 2)	Examination entry for Michaelmas term practicals Hilary term submissions and all courses assessed by invigilated written examination in Trinity term
Friday 14th March (week 8)	Hilary term lectures end Hilary term mini-projects released
Friday 4th April, 12 noon (week 11)	Hilary term mini-project submission deadlines
Trinity Term	
Monday 20th April (week 0)	Provisional start date for first set of Trinity term examinations
Monday 28th April (week 1)	Trinity term lectures begin
Thursday 15th May (week 3)	Examination entry for Hilary and Trinity practicals Trinity term submissions (including dissertation)
Monday 2nd June (week 6)	Provisional start date for second set of Trinity term invigilated examinations
Monday 2nd June, 12noon (week 6)	Dissertation submission deadline
Friday 21st June (week 8)	Trinity term lectures end
Monday 24th June – Wednesday 26th June (week 9)	Trinity term take-home examinations released between these dates
Wednesday 26th June – Friday 28th June (week 9)	Submission deadlines for Trinity term take-home examinations between these dates*

* Trinity term mini-project release and submission dates to be confirmed.

B Case Studies

The following table details some examples of possible pathways through the Programme. These case studies are for illustrative purposes only and show the breadth and diversity of the programme. Many other paths through the course are possible — and in fact much more eclectic or more generalist selections of courses may be appropriate for students who have not settled on a specialisation they intend to pursue eventually. Indispensable courses ("core") for each given case study are indicated in bold. 1 unit=16 lectures; at least 10 units have to be taken over three terms. Note that some of the Case Studies below are sufficiently broad to allow multiple pathways within them, however you should ensure that your chosen pathway allows you to fulfil the requirements for the overall number of units and the number of assessed units. Please see the examination conventions for further details of these requirements.

Pathway	*MT*	*HT*	*TT*
Generalist Theoretical Physicist *“TEORICA UNIVERSALIS”* **Core 6.25 units** Total 10.25-12.25 units	**1. QFT 24** **2. Kinetic Theory 28** **3. GR I 16** **4. Pert. Methods 16**	1-3. *Three of* **Noneq. Stat. Phys 16** Advanced QFT 24 Adv. Fluid Dyn. 16 Collisionless Plasma Physics 18 Random Matrix Theory 16 Soft Matter 8 Cosmology 16 Quantum Matter 16	1-3. *Three of* Quantum Matter II 20 Renormalisation Group 16 The SM and Beyond I 16 The SM and Beyond II 16 Dissertation
Applied Mathematician *“APPLICATA”* **Core 7.75 units** Total 11.25 units	**1. Kinetic Theory 28** **2. GR I 16** **3. Pert. Methods 16** **4.** Num. Lin. Algebra 16 **5.**	**1. Adv. Fluid Dyn. 16** ***2.*** *One of* **Noneq. Stat. Phys 16** Geophysical Fluid Dynamics 16 Collisionless Plasma Physics 18 Galactic Dyn. 16 GR II 16 Random Matrix Theory 16 **3. Applied Complex Variables 16** **4.** Networks 16 **5.** Riemannian Geometry	Collisional Plasma Physics 18 Dissertation

Fluid Dynamicist *“CONTINUA”* **Core 3.75 units** Total 10.75 units	**1. Kinetic Theory 28** **2. Pert. Methods 16**	**1. Adv. Fluid Dyn. 16** **2.** Soft Matter Phys. 16 **3.** Collisionless Plasma Phys. 18 **4.** Geophysical Fluid Dyn. 16 **5.** Applied Complex Variables 16 **6.** Noneq. Stat. Phys 16	1. Collisional Plasma Physics 16 2. Dissertation
Mathematician with a physics streak *“GEOMETRA”* **Core 5.5 units** Total 10–11 units	**1. QFT 24** **2. GR I 16** ***3.*** *One of* Groups & Repr. 24 Algebraic Topology 16 Algebraic Geometry 16	**1. String Theory I 16** ***2.*** *One of* Advanced QFT 24 SUSY & SUGRA 16 GR II 16 Geom. Group Theory 16 Riemannian Geometry 16 Low Dimensional Topo. 16 Random Matrix Theory 16	**1. String Theory II 16** ***2.*** *Three of* CFT 16 The SM and Beyond I 16 The SM and Beyond II 16 Astroparticle Phys. 16

Particle Phenomenologist *"PARTICULATA"* **Core 5.5 units** Total 10 units	**1. QFT 24** **2. Groups & Repr. 24** **3.** *One of* GR I 16 Pert. Methods 16	**1. Advanced QFT 24** **2. SUSY & SUGRA 16** **3.** *Two of* String Theory I 16 GR II 16 Cosmology 16	*Two of* String Theory II 16 The SM and Beyond I 16 The SM and Beyond II 16
Hard-core String Theorist *"SUPERCORDULA"* **Core 7.5 units** Total 11.5 units	**1. QFT 24** **2. Groups & Repr. 24** **3.** *One of* GR I 16 Pert. Methods 16 Algebraic Geometry 16	**1. Advanced QFT 24** **2. String Theory I 16** **3.** *One of* SUSY & SUGRA 16 Riemannian Geometry 16 Low Dimensional Topo 16 GR II 16 Cosmology 16	**1. String Theory II 16** **2. CFT 16** 3. *One of* The SM and Beyond I 16 The SM and Beyond II 16
Condensed Matter Theorist *"CONDENSATA"* **Core 3.5 units** Total 11.5–12.5 units	**1. QFT 24** **2.** Advanced Quant. Th. 20 3.*One of* Kinetic Theory 28 Topological Quantum Theory 16	**1. Noneq. Stat. Phys. 16** **2.** Advanced QFT 24 **3.** Adv. Fluid Dyn. 16 **4.** Random Matrix Theory 16 **5.** Low Dimensional Topo. 16	**1. Quantum Matter 16** **2.** Quantum Matter II 20 **3.** Renormalisation Group 20 **4.** CFT 16
Hard-core Hard Condensed Matter Theorist *"DURACELLA"* **Core 4.25 units** Total 10.5–11.25 units	**1. QFT 24** **2.** Kinetic Theory 28 **3.** Pert. Methods 16	*Three of* 1. Noneq. Stat. Phys. 16 2. Advanced QFT 24 3. String Theory I 16 4. Low Dimensional Topo 16 5. Adv. Fluid Dyn. 16 6. Random Matrix Theory	**1. Quantum Matter 16** **2.** Renormalisation Group 20 **3.** CFT 16
Soft Condensed Matter Physicist/Biophysicist *"MOLLIS"* **Core 5.25 units** Total 10.25 units	1. QFT 24 **2. Kinetic Theory 28** **3.** Pert. Methods 16 4. Networks 16	**1. Adv. Fluid Dyn. 16** **2. Noneq. Stat. Phys. 16** **3. Soft Matter 16** **4.** Collisionless Plasma 18	**1. Topics Soft Matter 8** **2.** Dissertation

<table>
<tr><td>All-round Astrophysicist
“ASTRA-STELLA”
Core 3.75 units Total 10.75–11.75 units</td><td>**1. Kinetic Theory 28**
2. GR I 16
3. *Two of*
QFT 24
Quantum Processes in Hot Plasma 16
Pert. Methods 16</td><td>**1.Galactic Dyn. 16**
2. Cosmology 16
3. *Three of*
Adv. Fluid Dyn. 16
Collisionless Plasma Physics 18
Rad. Proc and High Energy Astro 16
Astroparticle Phys. 16
High Energy Density 16</td><td>1. Dissertation</td></tr>
<tr><td>Dedicated Cosmologist
“COSMICOSMICA”
Core 3 units
Total 10.75 units</td><td>**1. GR I 16**
2-5.
QFT 24
Kinetic Theory 28
Pert. Methods 16</td><td>**1. Cosmology 16**
2. GR II 16
3. Galactic Dyn. 16
4. Astroparticle Phys 16
5.</td><td>1. Low Dimensional Topo. 16</td></tr>
<tr><td>Geophysicist/ Climate Physicist
“GAIA”
Core 2 units
Total 7.75 units</td><td>1. Kinetic Theory 28
2. **Pert. Methods 16**
3. Networks 16</td><td>**1. Geophysical Fluid Dynamics 16**
2. Advanced Fluid Dynamics 16
3. Noneq. Stat. Phys. 16</td><td>1. Dissertation</td></tr>
<tr><td>Plasma Theorist
“PLASMA”
Core 5.75 units
Total 10.75 units</td><td>**1. Kinetic Theory 28**
2. Pert. Methods 16
3. Quantum Processes in Hot Plasma 16</td><td>**1. Adv. Fluid Dyn. 16**
2. Collisionless Plasma Physics 18
3. Noneq. Stat. Phys. 16
4. *One of*
Applied Complex Variables 16
High Energy Density 16</td><td>1. Dissertation
2. Collisional Plasma Physics 16</td></tr>
</table>

C Suggested Dissertation Topics

Supervisor: **Prof Alexander Schekochihin**

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

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

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)

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)

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 Andrew Mummery**

(andrew.mummery@physics.ox.ac.uk)

Tidal disruption events as a probe of astrophysical black holes

Abstract::

Occasionally an unfortunate star can be scattered onto a near-radial orbit about a supermassive black hole in a galactic centre, at which point the tidal force from the black hole can overcome the self-gravity of the star, ripping it apart and igniting a transient flare of light from a previously quiescent galactic centre. This phenomenon has been observed in around 100 galaxies over the last 20 years, and this growing data set is a unique probe of the supermassive black holes in our Universe. The student will examine how we can use these events to probe black hole physics through accretion disc theory, and will have the opportunity to work with astronomical data if they wish.

Reading:
https://ui.adsabs.harvard.edu/abs/2020MNRAS.492.5655M/abstract
https://ui.adsabs.harvard.edu/abs/2024MNRAS.527.2452M/abstract
https://arxiv.org/abs/2104.14580

Supervisor: **Dr Anton Sokolov**

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

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)

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 ProfileNora S. Martin, Chico Q. Camargo, Ard A. Louis doi:
https://doi.org/10.1101/2023.05.24.542053

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)

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.

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 how

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: **Prof Caroline Terquem**

(caroline.terquem@physics.ox.ac.uk)

Parametric Instabilities in Fluids

Abstract: When the pivot of a simple pendulum is subject to a periodic acceleration, the rest state becomes unstable if the frequency of the acceleration is close to twice that of the pendulum natural frequency. This is called a 'parametric' instability as it is caused by the time-dependence of one of the parameters (here the gravitational field). In fluids, similar instabilities arise when a forced oscillation resonate with waves that can propagate freely in the fluid (normal modes of oscillation). Systems subject to periodic forcing can be described by Mathieu's equation and Floquet's theory, which is a convenient formalism to study the conditions for instabilities. Parametric instabilities can also be described by (non-linear) mode-mode interactions, which is a better framework to understand how the energy of the oscillation is exchanged with that of normal modes.

Pre-requisites: Basic Fluid Dynamics

Supervisor: **Dr Christopher Couzens**

(couzens@maths.ox.ac.uk)

Equivariant localization and AdS4 solutions in supergravity

Abstract:

When studying holography, we often want to compute various types of observables. Typically, these are given by integrals over a compact space. Given an explicit solution it is then easy to compute these integrals, however finding explicit solutions is difficult. Equivariant localization gives a way of avoiding the need for explicit solutions. Instead, it uses the topology of the space to reformulate integrals in terms of fixed points of a symmetry of the space. We will use this technique to study a class of AdS4 solutions in massive type IIA supergravity. The project will begin by learning about equivariant localization before applying these techniques to some new examples.

Prerequisites:

General Relativity and/or Differential Geometry (Riemannian manifolds).

Supervisor: **Prof Ed Hardy**

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

The Strong CP Problem and Axioms

Abstract:

One of the outstanding mystery 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

Hamiltonian Truncation and Extreme 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 Jason Lotay**
(lotay@maths.ox.ac.uk)

Einstein Manifolds

Abstract:
Einstein manifolds are central objects of study in geometry since they satisfy a very natural constraint on the curvature, which essentially goes back to the initial studies of curvature in dimensions beyond 2 (i.e. Riemannian geometry). They are also clearly connected to mathematical physics, as they satisfy (a version of) Einstein's vacuum field equations of gravity from General Relativity.
Despite being studied for about a century, Einstein manifolds remain very mysterious and very much form part of current research. Many examples are now known, but they arise from many different methods of construction, from the use of symmetries (i.e. groups) and ODEs, to the delicate analysis of PDEs, to algebraic and complex geometry. Moreover, the Einstein condition depends on a choice of real (cosmological) constant, and whether the constant is negative, zero or positive leads to very different geometry, topology and physics. The general existence question for any case currently seems far out of reach.
The aim of this project will be to study existence and examples of Einstein manifolds and their construction, and potentially to look at their properties.
Several different approaches are possible within this topic, and one can also take a more mathematics or more physics perspective. Some examples are the following:

- positive Einstein manifolds: symmetry and ODE techniques;
- zero Einstein (i.e. Ricci flat) manifolds: Hitchin-Thorpe inequality; special holonomy;
- negative Einstein manifolds: hyperbolic manifolds; PDE methods
- Kaehler-Einstein manifolds: connections to algebraic and complex geometry.

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: (to take at least some of these alongside the project) Differentiable Manifolds, Riemannian Geometry, General Relativity I, Lie Groups
Useful: (to take some of these before or alongside the project, definitely optional) General Relativity II, Algebraic Geometry, Algebraic Topology, some background in partial differential equations might be helpful but is definitely optional.

Reading list:
Besse, Einstein manifolds, 1987.
Joyce, Riemannian holonomy groups and calibrated geometry, 2007.
Further references:
Böhm, Inhomogeneous Einstein metrics on low-dimensional spheres and other low-dimensional space, Invent math 134 (1998), 145–176.
Hitchin, Compact four-dimensional Einstein manifolds, J. Diff. Geom. 9 (1974), 435-442.
Fine & Premoselli, Examples of compact Einstein four-manifolds with negative curvature, J. Amer. Math. Soc. 33 (2020), 991-1038.
Szekelyhidi, An introduction to extremal Kähler metrics, 2014.

Supervisor: **Prof Joseph Conlon**

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

The First Second of the Universe

Abstract:

For all the advances in early universe cosmology, little is known about most of the evolution of the universe in the period prior to Big-Bang Nucleosynthesis. The dissertation will explore this epoch; it would be expected to review the Standard Cosmology and use that as a launchpad to discuss other scenarios and the ways that observational signatures can arise from these epochs. Topics considered here could include cosmic strings, gravitational waves, string moduli, phase transitions and axions: the dissertation should include a detailed account of at least one scenario different from the Standard Cosmology.

Reading:
https://arxiv.org/abs/2006.16182

Supervisor: **Prof Julia Yeomans**

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

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)

Scattering Amplitudes

Abstract: Scattering amplitudes are one of the basic outputs of quantum field theory for testing theoretical predictions in the LHC. They also have many fascinating mathematical properties, both at tree level where there are interesting recursion relations, relations to twistor theory, polyhedra and positive geometries, and CHY/ambitwistor-string formulae, and at loops where they interact with the mathematical theory of polylogs. There are many directions that a project can take in reviewing various approaches, for different theories including string theory, where string amplitudes are their own corner of the subject, and using recursion methods to calculate examples.

Prerequisites: Quantum Field Theory is essential. Advanced Quantum Field Theory and Supersymmetry are also useful.

Reading list:
Henriette Elvang & Yu-tin Huang (Scattering Amplitudes, https://arxiv.org/abs/1308.1697

Supervisor: **Dr Nick Jones**

(jonesn@maths.ox.ac.uk)

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 reviewing field theoretic approaches to EE, 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:
An Introduction to Topological Phases of Matter
Depending on directions taken: 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: **Dr Pieter Bomans**

(bomans@maths.ox.ac.uk)

The Witten index of the BMN Matrix Quantum Mechanics

Abstract:

The BMN conjecture states that scattering amplitudes in M-theory on a plane wave background can be computed using a matrix quantum mechanics (MQM), the BMN MQM. This is perhaps the simplest setup to study the gauge/gravity correspondence and provides an ideal testbed to learn about the intricacies of quantum gravity without invoking full-fledged quantum field theory. The goal of this project is to study a powerful invariant of this MQM, namely it's Witten index. The Witten index is defined as a trace over the Hilbert space weighted by a Boltzman factor and the fermion parity operator and counts the ground states of the theory. In this thesis you will derive a matrix integral expression for the contributions associated to each vacuum and analyse the resulting index using a mix of analytic and numeric tools reproducing and extending the results in the reference below.

Prerequisites:
Quantum Mechanics, QFT, Advanced QFT and Supersymmetry and Supergravity

Reading: https://arxiv.org/abs/2404.18442

Supervisor: **Prof Renaud Lambiotte**

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

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.

Supervisor: **Dr Romain Ruzziconi**

(ruzziconi@maths.ox.ac.uk)

Carrollian Structure of Scattering Amplitudes

Abstract:

The holographic principle states that gravity in a given spacetime region can be encoded on a lower-dimensional boundary of that region. Extending this paradigm beyond the anti-de Sitter (AdS) / conformal field theory (CFT) correspondence to the more realistic model of asymptotically flat spacetimes is part of an intensive ongoing research effort, referred to as flat space holography. In this project, we will focus on the so-called Carrollian holography approach, which suggests that gravity in four-dimensional asymptotically flat spacetime is dual to a three-dimensional Carrollian CFT living at null infinity. Examples of Carrollian CFTs can be constructed by taking ultra-relativistic limits of standard CFTs, which consist in taking the speed of light going to 0. One of the key ingredients of Carrollian holography is that scattering amplitudes for the bulk theory written in position space, called Carrollian amplitudes can be re-interpreted as correlation functions in the dual theory.
The goal of the dissertation is to make this holographic statement more precise by investigating the Carrollian properties of the amplitudes in position space at null infinity.
The first step will be to understand how Carrollian geometry at null infinity relates to the BMS symmetries in asymptotically flat spacetimes. Then, the objective will be to interpret the expression of the four-point boundary correlators in terms of Carrollian cross-ratios. The ultimate goal is to contribute to gaining more control over Carrollian CFT using bootstrap methods.

Prerequisites:

Recommended: General Relativity I, Quantum Field Theory I
Useful: Conformal field theory, General Relativity II, quantum field theory II, AdS/CFT correspondence

Reading:
Geometry at null infinity (especially Section II): https://arxiv.org/pdf/1409.1800
Introduction to CFT (especially chapter 3):
https://courses.maths.ox.ac.uk/pluginfile.php/97566/mod_resource/content/1/CFTlectures.pdf
The link between Carrollian geometry and BMS symmetries: https://arxiv.org/pdf/1402.5894
Definition of Carrollian amplitudes: https://arxiv.org/pdf/2212.1255 (especially Sections 1 and 2) and https://arxiv.org/pdf/2312.10138 (especially Sections 1 to 7).

Supervisor: **Dr Seyed Faroogh Moosavian**

(moosavian@maths.ox.ac.uk)

Aspects of Jackiw-Teitelboim Gravity

Abstract:

This project focuses on JT (Jackiw-Teitelboim) Gravity, a gravitational model in two spacetime dimensions that simplifies the study of quantum gravity. By examining key theoretical aspects, the project aims to explore JT Gravity, and its connections to quantum chaos, holography, and especially random matrix theory. The goal is to explore how this simplified gravitational model offers insights into the deeper structure of spacetime and quantum gravity.

Prerequisites:

Reading:

Solvable Models of Quantum Black Holes: A Review on Jackiw-Teitelboim, Gravity Thomas G. Mertens, Gustavo J. Turiaci, arXiv:2210.10846

JT Gravity as a Matrix Integral, Phil Saad, Stephen H. Shenker, Douglas Stanford, arXiv:1903.11115

JT Gravity and the Ensembles of Random Matrix Theory Douglas Stanford, Edward Written, arXiv:1907.03363

D Glossary of Key Terms

A list of useful terms for new students.

Battels: The charges made to a member of a college (student or Fellow) for accommodation, meals etc.

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.

College Office: The academic office based at your college who will be able to assist you with changing your examination entries if needed.

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.

Degree Days: Various days throughout the year on which students may graduate.

DGS: Director of Graduate Studies.

Don: A professor, a lecturer or a Fellow.

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 Regulations: Sometimes referred to as the 'Grey Book', the Examination Regulations govern all academic matters within the University.

Examination Schools: The building located on High Street where written examinations are held for the MMathPhys/MSc in Mathematical and Theoretical Physics degree, and where students hand in hard copies of their dissertations, mini-projects, and take-home examinations.

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

Invariants: A society run by students at the Mathematical Institute, which aims to promote Mathematics and to provide a social environment for students of Mathematics.

GSO: Graduate Studies Office, part of the central University.

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

Hilary term: The second term of an academic year, running from January to March.

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

Lectures Known as classes at some other institution, this is where the lecturer will present their subject to you as a larger audience. Classes at Oxford are where students split into smaller groups to work through problem sheets based on the lectures with a tutor and sometimes a teaching assistant.

Lecturer: Lecturers are those who have the responsibility to deliver lectures.

LGBTI∧3: A group of students aiming to provide a friendly environment for those LGBTQ-identifying individuals studying within the Mathematical Sciences.

Matriculation: Matriculation confers membership of the University on those students who are enrolled at the University of Oxford and following a degree-level course.

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.

Michaelmas term: The first term of an academic year, running from October to December.

Minerva: A system used by teaching staff to record attendance and marks for the students in their class at Maths. The class times, days and locations are exported from this system and are advertised to students through the departmental class lists.

Mirzakhani Society: A society at the Mathematical Institute for female and non-binary students.

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.

Oxford SU: Oxford University Student Union.

Papers: Constituent parts of an examination.

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.

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.

Sub fusc: Formal attire worn by students and academics on formal occasions, including matriculation, examinations and graduation.

Trinity term: The third term of an academic year, running from April to June.

Vac: Abbreviation of vacation.

Week 0: The week preceding the start of each term. Week 0 in Michaelmas Term is sometimes referred to as 'noughth week'.