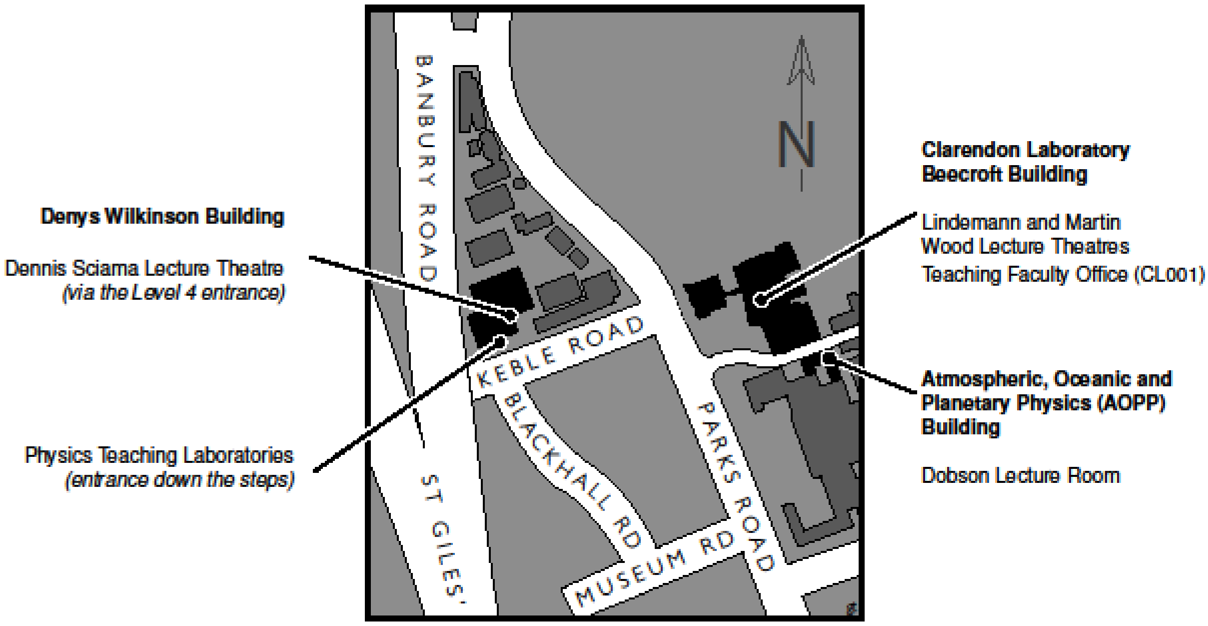
Physics Undergraduate Course Handbook 2018-2019

Third Year (Part B)

UNIVERSITY OF OXFORD

Map of the Department of Physics Buildings



Useful Department Contacts

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These notes have been produced by the **Department of Physics**. The information in this handbook is for the academic year Michaelmas Term 2018, Hilary Term 2019 and Trinity Term 2019.

Contents

Introduction to the handbook

A handbook is provided for each year of the programme, you may find it useful to skim the courses on topics available in later years. This handbook contains, amongst other things: comprehensive book/reading lists for the first year; important dates for the academic year; information about the undergraduate consultative committee (PJCC); and a list of people involved in organising the course. Please read this handbook thoroughly and refer to it frequently, as it will often contain the answers to many common questions.

Other useful sources of information:

Full details about the Practical Course are given in the *Practical Course Handbook* at http://www2.physics.ox.ac.uk/students/undergraduates

Please refer to the *Physics and Philosophy Course Handbook* at http://www2.physics.ox.ac.uk/students/undergraduates for all details of the Physics and Philosophy course that are not covered in the *Physics Undergraduate Course Handbook*.

For particular information about College teaching, students should contact their tutors. Further information about the courses can be obtained from the Department of Physics website http://www2.physics.ox.ac.uk/students/undergraduates and from the Physics Teaching Faculty.

In this document, Michaelmas Term (MT), Hilary Term (HT), Trinity Term (TT), refer to Michaelmas (Winter), Hilary (Spring) and Trinity (Summer) Terms of the academic year, respectively. The weeks in each term are numbered as 1^{st} week, 2^{nd} week and so on, with 0^{th} week being the week immediately before start of full term.

For full and up-to date information on lecture timetables, see www.physics.ox.ac.uk/lectures.

The examination times given in this handbook are based on information available in September 2018. These may be altered and the definitive times are those published by the examiners; these will be posted on the official examiners' web page.

The Examination Regulations relating to this course are available at https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters. If there is a conflict between information in this handbook and the Examination Regulations then you should follow the Examination Regulations. If you have any concerns please contact the Assistant Head of Teaching (Academic) by e-mail at carrie.leonard-mcintyre@physics.ox.ac.uk.

The information in this handbook is accurate as at **2 October 2018**, however it may be necessary for changes to be made in certain circumstances, as explained at http://www2.physics.ox.ac.uk/students/undergraduates. 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.

Important dates and deadlines

Michaelmas Term	Event	Time	Location
Week 1	Introduction to the Third Year	Mon 09:30	Lindemann Lecture Theatre
Week 1	BA Group Projects	09:00	Dennis Sciama Lecture Theatre
Week 1	Project Safety for BA students	***	
Week 2	Short Options: S20; S21; S27 and S28		
Week 4	Application for more practical work or vacation placement deadline		
Week 8	Entry for Part B	Fri	*

Hilary Term	Event	Time	Location
Week 4	BA Group Project Presentations	***	***

Trinity Term	Event	Time	Location
Week 1	Hand in BA projects	Mon 12:00	Examination Schools
Weeks 1- 4	Assessed Practicals	Mon/Tues	Teaching Laboratories Sign up on paper sheets outside the relevant lab in advance.
Week 3	Entry for Short Option choices	Fri	*
Week 4	Last day to do practicals	Tues 10:00	
Week 5	Year Group meeting		***
Week 5	Last day to get practicals assessed	Tues 10:00	BY APPOINTMENT ONLY
Week 5	Introduction to Major Options	Wed	***
Week 5	Deadline for completion of Practical Work	Fri 12:00	
Week 6	Hand in extra practical and extended practical reports	Mon 12:00	Teaching Faculty Office
Week 6	Major Option and MPhys project Choice	Fri	Online submission

* Students submit their entries via their College Office and Student Self Service.

** See https://www.ox.ac.uk/students/academic/exams/timetables for the exam timetables.

*** See http://www.physics.ox.ac.uk/lectures/ for lecture details.

Introduction to the Department of Physics

The Department of Physics

Please see the introductory section to the first year handbook for a broader introduction to the Department, the Faculty and lecture theatres etc. if you would like a refresher on those things.

Policies and Regulations

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 on the Oxford Students website www.ox.ac.uk/students/academic/regulations/a-z. In particular, see the Policy on recording lectures by students (located here: http://www.admin.ox.ac.uk/edc/policiesandguidance)

Data Protection

The Physics Department follows the general guidelines laid down by the University in regard to the provisions of the Data Protection Act 1998 (see http://www.admin.ox.ac.uk/dataprotection/ for details.) Only student information relevant to the organisation of the physics courses is held by the Department.

University Policy on Intellectual Property Rights

The University of Oxford has arrangements in place governing the ownership and exploitation of intellectual property generated by students and researchers in the course of, or incidental to, their studies. More details are available at https://researchsupport.admin.ox.ac.uk/innovation/ip/policy

Copyright

Guidance about copyright is published at https://www.ox.ac.uk/public-affairs/images/copyright**.** The University holds a licence from the Copyright Licensing Agency (CLA) which permits multiple copying (paper to paper) from most copyright-protected books, journals, law reports, conference proceedings and magazines for use by students and the course tutor on registered taught courses and non-credit-bearing short courses.

Good academic practice and avoiding plagiarism

"Plagiarism is presenting someone else's work or ideas as your own, with or without their consent, by incorporating it into your work without full acknowledgement. All published and unpublished material, whether in manuscript, printed or electronic form, is covered under this definition.

Plagiarism may be intentional or reckless, or unintentional. Under the regulations for examinations, intentional or reckless plagiarism is a disciplinary offence" see www.ox.ac.uk/students/academic/guidance/skills/plagiarism.

The Teaching Faculty uses "*Turnitin*" as a tool that allows papers (projects) to be submitted electronically to find whether parts of a document match material which has been previously submitted. All work submitted will be checked with Turnititin.

See https://weblearn.ox.ac.uk/portal/hierarchy/skills/generic/avoidplag for an online course on avoiding plagiarism.

Support for disabled students

"Disability is a much broader term than many people realise. It includes all students who experience sensory and mobility impairments, mental health conditions, long-standing health conditions, social communication conditions or specific learning difficulties where the impact on day-to-day life is substantial and long term." [ref: Student Handbook 17-18] The Department is able to make provision for these students contact the Assistant Head of Teaching (Academic), the Disability Contact for the Department, about your requirements. See http://www.admin.ox.ac.uk/eop/disab/ for more information. The *Examination Regulations* provides guidance for students with special examination needs. See the *Examination Regulations* http://www.admin.ox.ac.uk/examregs/ for more information.

Student Life, Support and Guidance

Every College has their own system 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 are available more widely in the University and from the Oxford Students website (www.ox.ac.uk/students/welfare), including information in relation to mental and physical health and disability. Students are encouraged to refer to http://www.ox.ac.uk/current_students/index.html for further information.

Your College tutors provide advice about the Physics courses, and information is also available from the Physics Teaching Faculty Office.

Complaints and appeals

If you have any issues with teaching or supervision please raise these as soon as possible so that they can be addressed promptly. In **Appendix D**, you will find precise details for complaints and appeals.

Opportunities for skills training and development

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 skills and academic writing - through the Oxford Students website http://www.ox.ac.uk/students/academic/guidance/skills.

Employability and careers information and advice

The University Careers Service (at 56 Banbury Road) provides careers advice for both undergraduates and graduates (see http://www.careers.ox.ac.uk). One of their staff specialises in advising physics students. The service has excellent contacts with many employers, and maintains links with ex-Oxford students working in many different types of job. The Careers Service also has comprehensive details on post-graduate study in the UK or abroad). Information on research opportunities is also available from the sub-Departments of Physics and from tutors.

Departmental representation - The Physics Joint Consultative Committee (PJCC)

The PJCC has elected undergraduate members who meet twice in Michaelmas Term and Hilary Term, and once in Trinity Term to discuss both academic and administrative matters with academic staff representatives. The Department values the advice that it receives from this committee for improving the quality of lectures, practicals and other aspects of the physics courses. The PJCC responsibilities include updating *The Fresher's Guide,* updating the PJCC web site and web pages linked to the Teaching pages. See https://pjcc.physics.ox.ac.uk/.

Opportunities to provide evaluation and feedback

The **PJCC** organises the online distribution and collection of data from the electronic lecture feedback. See https://pjcc.physics.ox.ac.uk/ for more information. These are a valuable source of information for the Department's Academic Committee, which organises the lectures and is in charge of the Physics courses. The feedback provided is used as part of the continuing review and development for Departmental, University and QAA quality assurance. Students are encouraged to make full use of the on-line management system for feedback on the practicals.

Students on full-time and part-time matriculated courses are surveyed once per year on all aspects of their course (learning, living, pastoral support, college) through the Student Barometer. Previous results can be viewed by students, staff and the general public at: https://www.i-graduate.org/services/student-barometer/ Final year undergraduate students are surveyed instead through the National Student Survey. Results from previous NSS can be found at www.unistats.com.

Mathematical, Physical and Life Sciences (MPLS) Division and University Representation

Student representatives sitting on the Divisional Board are selected through a process organised by the Oxford University Student Union (OUSU). Details can be found on the OUSU website along with information about student representation at University level.

An undergraduate student, usually a student member of the PJCC, is a representative on the Undergraduate Joint Consultative Committee of the Division. More details can be found at https://www.mpls.ox.ac.uk/intranet/divisional-committees/undergraduate-joint-consultative-forum.

Enterprise and entrepreneurship

Enterprising Oxford is an online map and guide to innovation and entrepreneurship in Oxfordshire, developed at the University of Oxford. Whether you have an idea, a start-up or a well and truly established venture, Enterprising Oxford highlights opportunities to develop further or help support others. See http://eship.ox.ac.uk/ for more information.

The Institute of Physics

This organisation offers a number of facilities for students through its 'Nexus' network. They also have information about careers for physicists. Students are encouraged to join the IoP, with membership free for undergraduates. See http://www.iop.org/ for more information.

Third Year 2018-2019

Introduction to the Third Year

All Physics and Physics and Philosophy third years are **required** to attend the Introduction to the third year on Monday morning at 09:30 of 1st week of Michaelmas Term. There you will hear a brief introduction to the second year course.

Aims and Objectives

The first year handbook contains an overview of the broader course intentions, and includes information about subject benchmark statements, the split of Department and College teaching more broadly, expectations of study and workload etc. Please do refresh yourself on these areas as appropriate. This handbook focuses on new information needed for the third year of your programme.

The BA and MPhys course: **which course should I do?**

At the start of Michaelmas, you must decide whether you will take the three year course (BA) or the four year course (MPhys). Your tutor will have received the results of your Part A examination over the long vacation, and if you have any doubts concerning which course you should take you should discuss the situation carefully with your tutor in the light of your examination results.

There is also an option to exit the MPhys course after your Part B examinations at the end of the third year (see Changing from the MPhys to the BA).

You should bear in mind that the four year course is designed to be challenging and will involve an appreciable amount of advanced work. You will also be expected to work more independently than during your first three years.

Changing from the MPhys to the BA (MPhys Exit)

Students **must make the decision** about doing the BA or MPhys course by:

(i) the beginning of MT 0th week with a firm deadline of **Friday noon of 1st week**. Students thinking of taking the BA course, but undecided by MT 0thweek, should tentatively sign up for a BA group project so that they can be assigned one at the start of term. Later changes are not normally permitted because of the impact on the BA group projects.

(ii) if you want to change to the BA after the deadline of **Friday noon of 1st week,** you can only exit after the 3rd year examinations i.e. after publication of the Part B results.

This exit route is available to all MPhys students until they complete Part C, but, as you would expect, the award of the BA precludes the possibility of ever taking Part C and obtaining the MPhys.

A MPhys classification **does not** have an equivalent BA classification. Once you have taken the MPhys examination, you receive a MPhys degree and are **ineligible** for a BA degree

Practical Work

The examiners' requirement for practical work for Part B is **12** days, but note that your computer lab record will only show 10 days, since 2 are awarded for the mini project write up.

It is possible to substitute for 6 days of practical work, by taking a second short option, but you must carry out a mini project plus one other 2 day practical.

There is no practical work in Hilary but students should write a report on the mini project they have done. The practical report write-up is part of the training in written communication skills and is organised by your tutor; please see them for further information.

The *Practical Course Handbook* and https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters show more details.

Mini-project

The mini project takes place in Michaelmas Term and amounts to 4 days of practical credit: 2 conventional days plus an extra 2 days of work which is then written up as the mini project report. The extra days of mini project credit are not shown on your practical record, so the total credit on the computer record is 10 days.

Students normally write their first draft during the Christmas Vacation

College tutors review the first draft during Hilary Term and provide one set of written and/or oral feedback. Students normally write their second draft during Hilary Term.

College tutors mark the second draft during Trinity Term as a percentage using the University's USM scale:

70%+	1st class	First Class
60-69%	2.1	Upper second
50-59%	2.2	Lower second
40-49%	3rd class	Third
30-39%	Pass	Pass
<30%	Fail	Fail

The majority of projects should be marked in the range 60-75%, with any competent report receiving a mark of at least 60% and any good report receiving a mark of at least 70%. Higher or lower marks can be awarded for particularly strong or weak reports, but marks below 50% should only be awarded where the student has made little or no serious attempt, and marks above 85% should only be awarded for quite exceptional reports.

As in BA and MPhys reports, marking reflects the clarity and rigour of the report, and not the experimental work: a well-documented failure can receive high credit. There is no suggested length for the report, which will in any event vary greatly for different projects. Similarly there is considerable flexibility on questions of style, but a top quality report should include all the usual components: introduction, outline methods, results, analysis of results including errors, and discussion and conclusions. In most cases suitable diagrams will be included to illustrate the results. Students may refer to the script for experimental details, but a good report should include at least an outline description of the underlying method.

College tutors return the percentage mark to Carrie Leonard-McIntyre by Friday of 2nd week of Trinity Term.

Short Options

Short Options are intended to introduce either specialist topics or subjects outside the mainstream courses. They allow students to experiment with new material without significant prejudice to their degree class, as they carry a low weighting.

At least one Short Option must be offered in Part A. A second Short Option may be offered in place of 6 days of practical work. Students electing to take this choice must inform the Assistant Head of Teaching (Academic) by e-mail at carrie.leonard-mcintyre@physics.ox.ac.uk by the end of Michaelmas Term.

Language Option

The language option will involve 32 hours of classes together with associated work in Trinity Term. It can be used to replace the Short Option paper.

A course is offered in French every year. Courses in German or Spanish are offered in alternate years. In Trinity Term 2019, the language courses will be French and German. The minimum entry requirement is normally an A at GCSE in the relevant language (or equivalent).

There will be a presentation for those interested in taking a language option at the Language Centre, 12 Woodstock Road. See the Physics *Lecture list* at http://www.physics.ox.ac.uk/lectures/ for details.

There is a preliminary test in the middle of Hilary Term to determine eligibility to take this option. The *Examination Regulations* reads: "Approval shall not be given to candidates who have, at the start of the course, already acquired demonstrable skills exceeding the target learning outcomes in the chosen language".

The language options final assessment is based on the syllabus and learning outcomes published by the Language Centre.

Students may offer to do the language option on more than one occasion provided it is a different language. For example a student can do French in their second year and Spanish (German) in their third year, subject to eligibility to take this option by the preliminary test in the middle of Hilary Term.

Alternative subjects

Students may request to substitute their first or second short option with another pre-existing course from another department of similar level and workload and where an appropriate pre-existing examination paper or other method of assessment is available. Such requests require the approval of the external department, the Head of Teaching within the Department of Physics and of the college. The assessment mark provided by the other department will be used directly by the Physics Examiners.

Application must be made via the Assistant Head of Teaching (Academic) by e-mail to carrie.leonard-mcintyre@physics.ox.ac.uk to replace the compulsory Short Option paper in Part A or Part B; the deadline is Friday of 4th week Michaelmas Term.

The application will only be agreed if the proposed course and an examination paper already exists within the University, and the alternative subject is considered appropriate. Students will be advised of the decision as soon as possible.

Pre-approved subjects

Several alternative subjects that have been pre-approved and are offered by other faculties or departments can be studied in place of one (or two) short options are:

(i(i) Supplementary Subject (History and Philosophy of Science): this is a paper offered within the University by other departments. S20: History of Science and S21: Philosophy of Physics are examined in the Supplementary Subject (History and Philosophy of Science) paper. Physics students may substitute such a paper instead of two short options. Alternatively S20: History of Science or S21: Philosophy of Physics can be offered as a short option.

(ii) Anyone wishing to do the S20: History of Science course should attend the first lecture, see the Physics *Lecture list* at http://www.physics.ox.ac.uk/lectures/

It is especially important to be present at the first lecture, immediately after which tutorial groups for the term will be arranged. More details can be found at http://course.chem.ox.ac.uk/history-and-philosophy-of-science-mt.aspx

(iii) S27: Philosophy of Space-Time and S28: Philosophy of Quantum Mechanics are offered by the Philosophy Faculty. S27: Philosophy of Space-Time and S28: Philosophy of Quantum Mechanics are examined in the Intermediate Philosophy of Physics paper.

If you wish to offer any of the above options, please inform the Assistant Head of Teaching (Academic) by e-mail at carrie.leonard-mcintyre@physics.ox.ac.uk by 2nd week of Michaelmas Term to ensure that you are entered for these examinations correctly.

Please note: Students must seek permission from their College tutors to study these topics as there will be a financial cost for classes and/or tutorials. The examination dates for the Supplementary Subject (History and Philosophy of Science) and the Intermediate Philosophy of Physics papers **are** different from the Physics Short Option examination date. No examination results will be released before the completion of all the Physics examinations.

More practical work

There are two ways to do extra practical work instead of a short option; extra practicals, or an extended practical. Extra practicals are simply more of the same experiments carried out for the basic quota, whereas extended practicals are effectively a small project. Permission to do extra practical work can be obtained by emailing TeachingAdmin@physics.ox.ac.uk, clearly stating which of the options below you wish to apply for.

The application must be made before noon on Friday of 4th week of Michaelmas Term. Applications submitted late will not be considered.

(a) Extra practicals

Extra practicals are an additional six days of standard practicals. You can only book for those practicals allocated to you by the SPIRe (Student Practical Information Record). If you want to work out of allocation you must see what is free on the day. Each of the extra practicals must be marked at least S on your SPIRe record, and you must write up one of the practicals, selected at random. **Students will be informed which practical to write up by noon on Wednesday of 4th week of Trinity Term**. No tutor input for this Report will be allowed. Students must submit one printed copy and an electronic copy (by e-mail attachment) of their report to the Physics Teaching Faculty Office (**Neither** Examination Schools **NOR** the Physics Teaching Laboratories will accept your reports) before noon on Monday of 6th week of Trinity Term. All work submitted will be checked with Tunititin.

Please ensure you write your candidate number **ONLY** on the report and **NOT** your name/college so that the reports can be marked anonymously.

The six extra days practical work will begin only when the normal practical quota has been completed. They should be booked and grades entered on the SPIRe as usual. **Part A students doing the six additional days of practicals in Part A will not be allowed to repeat this option for Part B.** You may work alone or with a partner. It does not matter which course your partner is registered for or if they are not doing extra practicals.

(b) Extended practicals

Extended practical work must have the support of an appropriate supervisor, and must be equivalent to six days practical work. If you need assistance finding a supervisor, please email TeachingAdmin@physics.ox.ac.uk once you have decided which area of physics you would like to work in. Students must submit one printed copy and an electronic copy (by e-mail attachment) of their report to the Physics Teaching Faculty Office. **Neither** Examination Schools **NOR** the Physics Teaching Laboratories will accept your reports, before noon on **Monday of 6th week of Trinity Term**. All work submitted will be checked with Turnitin.

Please ensure you write your candidate number ONLY on the report and NOT your name/college so that the reports can be marked anonymously.

Your supervisor may read and comment upon one draft only of your report before submission.

Alternatives to practical work

It is possible to replace some of the practical quota by a report on Physics-related vacation placements, by taking an extra short option.

(a) Vacation placements

Work carried out during a vacation placement may be submitted for practical course credit. Should you wish to gain credit for vacation work, you must firstly apply for approval to the Head of Teaching (teachingadmin@physics.ox.ac.uk) after the placement by returning the form AD12 at http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD12.pdf — project substitution for practical work in Michaelmas term before noon on Friday of 4th week of Michaelmas Term. It is possible to submit vacation work for practical credit in both Parts A and B, providing that the projects are distinct pieces of work.

You may only submit one vacation project per year for practical credit. More information is provided in the *Practical Course Handbook.*

Textbooks

A list of the books recommended by the lecturers is given in **Appendix A**. Your tutor will advise you as to what books you should obtain.

Major Options

In 5th week of Trinity Term, there will be a general introduction to the Major Options (for details consult the lecture list). By Friday of 6th week you will be required to indicate option choices in order of preference.

Alternative Major Options

It is possible to substitute another subject in place of a Physics Major Option, provided the course and exam already exist and are of sufficient weight. Permission must be sought from the Head of Teaching via the Assistant Head of Teaching (Academic) by e-mail to carrie.leonard-mcintyre@physics.ox.ac.uk in Trinity Term of your third year.

Fourth Year (MPhys) projects

The *MPhys Projects Trinity Term* handbook published at https://www2.physics.ox.ac.uk/students/undergraduates containing details of the projects for the MPhys will be circulated at the start of Trinity Term of your 3rd year and you must specify your choice of projects by Friday of **6th** week, of Trinity Term.

Third Year Patterns of Teaching

Timetable

The full Physics Undergraduate Lecture Timetable is located at www.physics.ox.ac.uk/lectures. This will show you when lectures are scheduled for all years.

Course structure

Course structure for BA: Four Papers including B3, B4, B6 and one other, from B1, B2 and B5; Short Option Paper, Mini Project; Part B Practical Work; BA Group Presentation and BA Project Report.

Course structure for MPhys: Six Papers: B1, B2, B3, B4, B5 and B6; Short Option Paper; Mini Project; Part B Practical Work.

Papers with the same teaching pattern are condensed into one row for ease of presentation.

Please note the total number of lectures is provided as a guide.

Lecture/tutorial ratio: 1 class/tutorial for every 5 lectures.

Students undertake 12 days of practical work.

Paper		**Faculty Teaching**	**College Teaching**
	Term	**Lectures**	**Classes/Tutorial**
B1. Flows, Fluctuations and Complexity	MT	22	~ 4
	TT	2	
B2. Symmetry and Relativity	MT	22	~ 4
	TT	2	
B3. Quantum, Atomic and Molecular Physics	MT	22	~ 4
	TT	2	
B4. Sub-Atomic Physics	HT	22	~ 4
	TT	2	
B5. General Relativity and Cosmology	HT	22	~ 4
	TT	2	
B6. Condensed-Matter Physics	HT	22	~ 4
	TT	2	
Additional lectures	MT	3	
	HT	1	
	TT	3	
S01. Functions of a Complex Variable	TT	12	
S07. Classical Mechanics	HT	12	
S10. Medical Imaging and Radiation Therapy	TT	12	
S12. Introduction to Biological Physics	TT	12	
S14. History of Physics	MT	8	
S16. Plasma Physics	TT	12	
S20. History of Science	MT	8	
S21. Philosophy of Science	HT	16	
S22. Language Options	TT	8	
S25. Climate Physics	TT	12	

Paper		Faculty Teaching	College Teaching
	Term	**Lectures**	**Classes/Tutorial**
S27. Philosophy of Space-Time	MT	16	
S28. Philosophy of Quantum Mechanics	HT	16	
S30. Exoplanets	TT	12	
S31. Numerical Methods	TT	12	

Examinations

The FHS (Final Honour School in Physics), also called **Finals**, is taken in parts over the final two (BA) or three (MPhys) years of your course. The Examiners are a committee set up each year under the Proctors. The Finals Examiners include external examiners from other UK Universities and may be assisted by a number of Assessors to set and mark some individual papers, projects, etc. In general, papers for Prelims and Part A of Finals are not set and marked by the course lecturers; indeed the identity of the examiner for any paper is confidential. The identity of the candidates is hidden from the examiners; no communication between the examiners and the candidate (or the candidate's tutor) is allowed except via the candidate's College's Senior Tutor and the Junior Proctor. The questions are required to be set in conformity with the syllabus, whose interpretation is guided by previous papers except where there has been an explicit change of syllabus. The current syllabuses for the final examinations in physics are printed in **Appendix C**.

Assessment of Class

How the examiners work is their responsibility, subject to guidance from the Physics Academic Committee, and regulations laid down by the central bodies of the University. However, the following gives some indication of recent practice. Each paper is marked numerically. The numerical marks for each paper may be scaled to remove any first-order effect of a difficult (or easy) paper and these (scaled) marks are combined to give a total numerical mark.

Class	Descriptor
Class I (1)	the candidate shows excellent problem-solving skills and excellent knowledge of the material, and is able to use that knowledge in unfamiliar contexts
Class II.1 (2.1)	the candidate shows good problem-solving skills and good knowledge of the material
Class II.2 (2.2)	the candidate shows basic problem-solving skills and adequate knowledge of most of the material
Class III (3)	the candidate shows some problem-solving skills and adequate knowledge of at least part of the material
Pass	the candidate has made a meaningful attempt of at least one question

For the BA degree FHS Parts A and B are approximately weighted, 2: 3; for the MPhys FHS Parts A, B, C are approximately weighted 2: 3: 3.

Final Degree Classes are assigned on the basis of a careful consideration of the total numerical mark with the project and practical work taken into account.

Part B Examination

The examination will take place toward the end of Trinity Term.

BA (3 year course)	MPhys (4 year course)	Physics and Philosophy
Four Papers including B3, B4, B6 and one other, from: B1, B2 and B5 Short Option Paper Group Project Presentation BA Project Report Mini Project Practical Work	**Six** Papers: B1, B2, B3, B4, B5 and B6 Short Option Paper Mini Project Practical Work	Three or four papers in Philosophy and either three or five physics subjects, each carrying the weight of half a paper, chosen from a list of seven: the six Part B physics subjects and a paper on Classical Mechanics.

The material for the B papers will be covered by lectures, tutorials and classes concentrated in Michaelmas & Hilary Terms. Full details of the syllabuses for the written papers are given in **Appendix C**.

Assessment of Practical Work

The practical mark for the second and third year consists of marks for completing experiments and an assessed practical.

Practical Work	Part B
Completing Experiments [a]	30
Assessed Practical [b]	20
Total	**50**

The relative marks are made up as follows:

[a] Up to 30 marks as indicated for completing all experiments. Failure to complete the practical quota will attract the following penalty:

(a) A penalty of 2.5 marks will be deducted for each missed day of experiments.

(b) If more than 6 days of experiments are missed, the Examiners may penalise the student by lowering the final degree by one class.

[b] Up to 20 marks awarded by the Senior Demonstrator, based on both the quality of the entire logbook and the understanding of the Assessed Practical (chosen at random in advance for Part A) demonstrated by the student.

The precise details of how the practical marks are calculated are published in the Examination Conventions at https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters.

Marking of the Assessed Practical

The marks, which will be awarded by a Senior Demonstrator, will be based on **both** the quality of the **entire logbook** and the understanding of the **assessed practical** demonstrated by the student. An average student with an average logbook should expect to achieve ~15 marks.

Specific details pertaining to practical work are published in the *Practical Course Handbook*. Recommendations to the Finals examiners based on the S+ marks will be used for practical prizes and commendations. These recommendations will be made to the Finals examiners. It is important that students **consult their tutors early** in the event of difficulty with practical work.

More information on how to write up experiments can be found in the *Practical Course Handbook*.

Assessment of extra practicals and extended practicals

The marking of the extra practicals and extended practicals is based upon the following:

- Introduction and abstract
- Description of method/apparatus
- Experimental work/results and errors
- Analysis of results
- Conclusions
- Good argument in the analysis, the use of clear English and writing style. Clear diagrams/plots and references will also be taken into account
- Penalties for late work will be published in the Examination Conventions.

Examination Preparation

There are a number of resources available to help you. Advice is available from your College tutor and the Oxford Student Union. See http://www.ousu.org/ for the Student Union.

Examination Entry

Entry for the FHS Part B exam is at the end of 8th week of Michaelmas Term, and 3rd week of Trinity Term for Short Option choices (except for certain alternatives).

The *Examination Regulations* provide guidance for students with special examination needs. "... An application ... shall be made as soon as possible after matriculation and in any event not later than the date of entry of the candidate's name for the first examination for which special arrangements are sought." Please see The *Examination Regulations* http://www.admin.ox.ac.uk/examregs/ for more information.

See **Appendix B** for information about the types of calculators which may be used in Public examinations.

Examination Dates

After the examination timetables have been finalised they are available at https://www.ox.ac.uk/students/academic/exams/timetables.

Examination Conventions

Examination conventions are the formal record of the specific assessment standards for the course or courses to which they apply. They set out how your examined work will be marked and how the resulting marks will be used to arrive at a final result and classification of your award. They include information on: marking scales, marking and classification criteria, scaling of marks, progression, resits, use of viva voce examinations, penalties for late submission, and penalties for over-length work.

The Academic Committee is responsible for the detailed weightings of papers and projects. The definitive version will be published not less than one whole term before the examination takes place. The precise details of how the final marks are calculated are published on the Examination matters webpage at https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters.

Sitting your examination

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 Students website (www.ox.ac.uk/students/academic/exams/guidance).

Students are allowed calculators, except when the Examination Conventions published on the Examination matters webpage at https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters explicitly forbid their use in the examinations. The calculators must conform to the rules set out at in "Regulations for the Conduct of University Examinations: Part 10 Dictation of Papers,..., Calculators 10.3..." at http://www.admin.ox.ac.uk/examregs/2016-17/rftcoue-p10dopatuow-p-ccaominexam/ and the types of calculators which may be used in the Public examinations in **Appendix B**.

Examination Regulations

The regulations for the Preliminary examinations are published in the *Examination Regulations* are published at www.admin.ox.ac.uk/examregs/.

Examination Results

After your examination, your tutor will be told the scaled marks that you obtained in each paper and your overall rank amongst candidates in Prelims. This information will not be published, but will be provided to enable your tutor to give you some confidential feedback and guidance. Students are able to view their examination results at https://www.ox.ac.uk/students/academic/exams/results. Marks displayed in the Student Self Service are given as percentages.

Part B Examination Prizes

Prizes may be awarded for excellence in various aspects of the second year examination

- Scott prizes
- Gibbs prizes
- Project prizes
- Practical work prizes

Information about prizes available is normally published in the Examination Conventions for Physics and, Physics and Philosophy. Once prizes are awarded the prize list is published at http://www2.physics.ox.ac.uk/students/undergraduates

Past Exam Papers

Past examination papers and the data sheet are available on the Physics webpages. See http://www2.physics.ox.ac.uk/students for more details.

External Examiner and Examiners' Reports

There are no external examiners for Prelims. The names of the External examiners are published in the Examination Conventions see https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters. Students are strictly prohibited from contacting external examiners and internal examiners directly. If you are unhappy with an aspect of your assessment you may make a complaint or academic appeal (see https://www.ox.ac.uk/students/academic/complaints).

Academic Progress

Departments and colleges have responsibility for monitoring academic progress (including the use of OxCORT). Colleges are responsible for monitoring academic progress of their undergraduate students.

Physics and Philosophy

The physics component in Part B consists of three (or five if your elective paper is in physics) subjects drawn from the following list: B1. *Flows, Fluctuations and Complexity*, B2. *Symmetry and Relativity,* B3. *Quantum, Atomic and Molecular Physics*, B4. *Sub-Atomic Physics,* B5. *General Relativity and Cosmology,* B6. *Condensed-Matter Physics* and B7. Classical mechanics

Your selection must include at least two of the subjects B2, B5 and B7.

Papers B1-B6 are the same as the core Part B physics papers taken by MPhys students, which are examined in six 2-hour papers, as shown above. The B7 paper is specially set for P&P students, in the same format as the other six subjects in Part B, and 2 hours in length. You should have tutorials to prepare you for this paper.

The weights assigned to the Part B papers in the Finals algorithm are 1 for each 3-hour Philosophy paper and ½ for each 2-hour physics paper.

MMathPhys

We offer a taught masters course in Mathematical and Theoretical Physics as an alternative to the fourth year of the MPhys course, see http://mmathphys.physics.ox.ac.uk

Appendix A Recommended Textbooks - Third year

(main text * supplementary text)** ***Books listed as far as possible by Short Options and Examination Papers Lecturers will give more details at the start of each course***

B1. Flows, Fluctuations and Complexity

'Physical Fluid Dynamics', D. J. Tritton (CUP, 2nd edition, 1988), ISBN- 10: 0198544936**

'Elementary Fluid Dynamics', D. J. Acheson (OUP, 1990), ISBN-10: 019859679*

'Fluid Dynamics for Physicists', F E Faber, (CUP, 1995), ISBN-10: 0521429692*

'Nonlinear Dynamics and Chaos', S. H. Strogatz (Perseus, 1994), ISBN 0738204536**

'Physical Biology of the Cell', R. Phillips, J. Kondev & J. Theriot (Garland Science, 2008) **

'Biological Physics: Energy, Information, Life', updated 1st edition, Philip Nelson (W. H. Freeman & Co Ltd, 2008)**

'Physical Biology of the Cell', R. Phillips, J. Kondev & J. Theriot (Garland Science, 2008) **

'Biological Physics: Energy, Information, Life', updated 1st edition, Philip Nelson (W. H. Freeman & Co Ltd, 2008)**

'Molecular and Cellular Biophysics', M. B. Jackson (CUP, 2006) **

'Biochemistry' 3rd Ed, D. Voet & J.G. Voet, (John Wiley & Sons Inc, 2005) OR

'Biochemistry', 6th Ed., L. Stryer, et al (W .H. Freeman & Co Ltd, 2006)

'Mechanics of Motor Proteins and the Cytoskeleton', J. Howard, Sinauer Associates Inc. (ISBN) 0-87893-333-6).

B2. Symmetry and Relativity

Special Relativity

'Six not-so-easy pieces: Einstein's relativity, symmetry and space-time', R P Feynmann (Allen Lane, 1998)

'Introduction to Special Relativity', W Rindler, (OUP) **

'Einstein's miraculous year', J Stachel (Princeton, 1998)

'The Special Theory of Relativity', Muirhead (Macmillan)

'An Introduction to Special Relativity and its applications', F N H Robinson, (World Scientific)**

'Introducing Special Relativity', W S C Williams (Taylor & Francis, 2002) ISBN: 9780415277624

'Relativity made relatively easy', A. Steane (OUP) **

B3. Quantum, Atomic and Molecular Physics

'Atomic Physics', Chris Foot (Oxford Master Series in Physics) **

'Atomic & Quantum Physics', Haken & Wolf (Springer)

'Principles of Modern Physics', RB Leighton (McGraw Hill) *

'Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles', E Eisberg and R Resnick (Wiley)*

'Elementary Atomic Structure', G K Woodgate (Oxford) *

'Atomic Physics', J C Willmott (Wiley) Manchester Physics Series

'Laser Physics', S Hooker and C Webb (Oxford Master Series in Physics) **

'The Physics of Quantum Mechanics' J Binney and D Skinner, (Cappella Archive http://www.cappella.demon.co.uk/cappubs.html#natsci) *

'Principles of Lasers,' Orazio Svelto, (Plenum Publishing Corporation KLUWER ACADEMIC PUBL)
ISBN10: 0306457482, ISBN13: 9780306457487

'Laser Physics' Hooker and Webb, ISBN13: 9780198506911, ISBN10: 0198506910

B4. Sub-atomic Physics

'Quantum Mechanics', Franz Mandl *
'Quantum Mechanics', Eugen Merzbacher *
'An Introduction to Nuclear Physics', W.N.Cottingham and D.A. Greenwood *
'Nuclear and Particle Physics', W.S.C Williams *
'Elements of Nuclear Physics', W.E.Burcham *
'Introductory Nuclear Physics', Kenneth S. Krane *
'Particle Physics', B.R.Martin and G.Shaw*
'Introduction to Elementary Particle Physics', Alessandro Bettini*
'Particle Physics in the LHC Era', G.Barr, R.Devenish, R.Walczak, T.Weidberg *
'Introduction to High Energy Physics', Donald H. Perkins, *

B5. General Relativity and Cosmology

'Gravitation and Cosmology', Steven Weinerg (Wiley, 1972)
'Gravity- an introduction to Einstein's theory of general relativity', James Hartle (Addison Wesley)
'Spacetime and Geometry', Sean Carroll (Addison Wesley)
'General Relativity- an introduction to physicists', Michael Hobson, G. Efstathiou and A. Lasenby (Cambridge)
'An Introduction to Modern Cosmology', A. R. Liddle (Wiley, New York)
'Cosmological Physics', J. A. Peacock (Cambridge University Press)
'Principles of Physical Cosmology', P. J. E. Peebles (Princeton University Press)
'The State of the Universe', Pedro G. Ferreira (Phoenix 2007)
Thomas Moore "General Relativity Workbook" Palgrave (2012)

B6. Condensed-Matter Physics

'The Oxford Solid State Basics', Steven H Simons (OUP, June 2013) ISBN-10: 0199680779 | ISBN-13: 978-0199680771
'The basics of crystallography and diffraction', C Hammond (OUP)
'Introduction to Solid State Physics' C Kittel (Wiley) *
'Solid State Physics', J R Hook and H E Hall (Wiley) *
'The Solid State', H M Rosenberg (OUP) *
'Solid State Physics', N W Ashcroft and N D Mermin (Saunders)
'Solid State Physics', G Burns (AP)
'Solid State Physics', H Ibach and H Luth (Springer)
'States of Matter', David Goodstein (Dover publishing)

<u>Short Options</u>

S01. Functions of a Complex Variable

'Mathematical Methods for Physics and Engineering: A Comprehensive Guide', K F Riley, M P Hobson and S J Bence (CUP, 2002), ISBN 0521-81372 7 (HB), ISBN 0521-89067 5 (PB) **
'Mathematical Methods in the Physical Sciences', Boas
'Mathematical Methods for Physicists', Arfken
'Complex Variables', Spiegel

S07. Classical Mechanics†

'Mechanics (Course of Theoretical Physics), Vol 1', L D Landau and E Lifshitz (Butterworth Heinemann): Physics the Russian way - first volume of the celebrated 'Course of Theoretical Physics'.

'Classical mechanics', 5th ed, T.W.B. Kibble & F.H. Berkshire – good solid book `Analytical Mechanics' L. Hand + J. Finch – good solid book 'Classical mechanics', 3rd ed H. Goldstein, C. Poole & J. Safko. A classic text. In the US probably plays the same role for classical mechanics that Jackson does for electrodynamics.

For the mathematically erudite: 'Mathematical methods of classical mechanics', V.I. Arnold.

†also for **B7. Classical Mechanics**

S10. Medical Imaging and Radiation Therapy

Webb's Physics of Medical Imaging, 2nd ed, Flower, ISBN 9780750305730

Physics in Nuclear Medicine, 4th ed., Cherry Sorenson and Phelps, ISBN 9781416051985

Introduction to Radiological Physics and Radiation Dosimetry, Frank Herbert Attix, Sep 2008 ISBN: 978-3-527-61714-2

Fundamental Physics for Probing and Imaging, Wade Allison, Oxford (2006) ISBN 9780199203888 and 9780199203895

Useful resource:

3D Conformal Radiation Therapy - A multimedia introduction to methods and techniques Springer ISBN 978-3-540-71550-4

S12. Introduction to Biological Physics

'Biochemistry', D. Voet and J. Voet (Wiley)

'Molecular Biology of the Cell', B. Alberts et al. (Garland)

'Mechanics of Motor Proteins and the Cytoskeleton', J. Howard (Sinauer)

S14. History of Physics

'The beginnings of Western Science: the European Scientific Tradition in Philosophical, Religious and Institutional Contexts', D.C. Lindberg, , (Chicago, 1992)

'A History of Natural philosophy from the Ancient World to the Nineteenth Century E. Grant, ', (Cambridge, 2007)

'Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental life', S. Shapin and S. Schaffer, (Princeton, 1995)

'Galileo', J. Heilbron, (Oxford, 2010)

'The Birth of a New Physics', I.B. Cohen, (Norton 1985)

'Discipline and Experience', P. Dear, (Chicago, 1994)

'The Cambridge History of Eighteenth Century Science', R. Porter, ed., (Cambridge, 2002)

'The Maxwellians', B. Hunt, (Ithaca, 1991)

Reading:

'From Watt to Clausius', DSL Cardwell, (Heineman 1971)

'Image and Logic: A Material Culture of Microphysics', P. Galison, (Chicago, 1997)

'Gravity's Shadow: the search for Gravitational Waves', H. Collins, (Chicago, 2004)

S16: Plasma Physics

'Plasma Dynamics', R.O. Dendy (OUP)

'Introduction to Plasma Physics and Controlled Fusion: Volume 1, Plasma Physics' Francis F. Chen (Plenum)

S25. Physics of Climate Change

For a very accessible overview: D. Archer, "Global Warming, Understanding the forecast", 2nd Ed., (Wiley)

For a deeper look, but pitched at the right level for this course: R. T. Pierrehumbert, "Principles of Planetary Climate", (CUP)

For a compact summary for the busy undergraduate: S. J. Blundell and K. M. Blundell, "Concepts in Thermal Physics", 2nd Ed., Chapter 37

For a bit more detail: D. G. Andrews, "An Introduction to Atmospheric Physics", 2nd Ed. (CUP), Chapters 2 & 8 or J. Marshall and R. A. Plumb, "Atmosphere, Ocean and Climate Dynamics, An Introductory Text", (MIT), Chapters 2, 3, 9 & 12.

And for a highly influential, albeit controversial, take on climate change economics: W. Nordhaus, 'The Climate Casino: Risk, Uncertainty and Economics for a Warming World', (Yale), Chapters 13-16 & 18.

S30. Exoplanents

'The Exoplanet Handbook', Michael Perryman, (Cambridge University Press)

'Exoplanets', edited by Sara Seager, (University of Arizona Press)

The following more specialised textbooks are suitable for students who wish to read in detail beyond the examination syllabus:

'Transiting Exoplanets', Carole Haswell, (Cambridge University Press)

'Astrophysics of Planet Formation', Philip J. Armitage, (Cambridge University Press)

'Exoplanet Atmospheres', by Sara Seager, (Princeton Series in Astrophysics)

S31. Numerical Methods

'Computer Simulation using Particles', R.W. Hockney and J.W. Eastwood, Taylor and Francis (1988)

'Numerical Methods in Astrophysics', Bodenheimer, Laughlin, Rozyczka and Yorke, Taylor and Francis (2007)

'Riemann Solvers and Numerical Methods for Fluid Dynamics ', E.F. Toro, Springer (2009)

'Finite Volume Methods for Hyperbolic Problems', R. LeVeque, Cambridge University Press (2002)

'Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-dependent Problems', R. LeVeque, Society for Industrial and Applied Mathematics (2007)

Appendix B Note on Calculators for ALL Public Examinations*

The regulations are likely to follow recent practice which is:

A candidate may bring a pocket calculator into the examination provided the calculator meets the conditions set out as follows:

- The calculator must not require connection to any external power supply.
- It must not be capable of communicating (e.g. by radio) with any other device.
- It must not make a noise that could irritate or distract other candidates.
- It must not be capable of displaying functions graphically.
- It must not be capable of storing and displaying text, other than the names of standard functions such as 'sin' or 'cosh'.
- It must not be able to store programs or user-defined formulae.
- It must not be able to perform symbolic algebra, or perform symbolic integration or differentiation.
- Within the above, the calculator may be capable of working out mathematical functions such as sin(x), log(x), exp(x), x^y and it may contain constants such as π.
- The examiners may inspect any calculator during the course of the examination.

Notes:

These guidelines follow closely the regulations on the 'Use of calculators in Examinations' in the University *Examination Regulations* ('The Grey Book') and at www.admin.ox.ac.uk/examregs/2016-17/rftcoue-p10dopatuow-p-ccaominexam/ The exact requirements in a given year will be published by the Examiners. For some Prelims papers in Maths calculators are not allowed at all.

The intention of the rules is to prevent the possibility of a candidate obtaining an advantage by having a powerful calculating aid (or of reading stored information as a substitute for knowing it). It is appreciated that candidates may already own calculators that are excluded by these rules. In such a case the candidate is responsible for obtaining a more basic calculator that is within the rules, and for becoming familiar with it in advance of the examination.

*** for the Physics papers when the use of calculators are permitted**

Appendix C Syllabuses for the Third Year (Final Honour School – Part B)

A knowledge of the topics in the syllabuses for the four compulsory physics Prelims papers and the compulsory material for Part A will be assumed. Emphasis will be placed on testing a candidate's conceptual and experimental understanding of the subjects. The word 'qualitative' indicates that the treatment of the topic will outline the physical principles involved, may include order of magnitude estimates, but will not be a full mathematical treatment.

Each of the physics B papers is a 2-hour paper,
Answer 2 questions from 4 in each section offered; with each question worth 25 marks.

B1. Flows, fluctuations and complexity

Fluxes and conservation principles, The Navier-Stokes equation Solution for Poiseuille flow, Reynolds's experiment. Dynamical similarity, the Reynolds number. Phenomena of instability, chaos and turbulence.

Vorticity, Kelvin's circulation theorem. Ideal fluid flows without vorticity. Bernoulli's theorem, lift force, hydraulic jumps. Boundary layers. Very viscous flows: Stokes' law, biological motility at low Reynolds number. Sound waves, shocks.

Flows in phase space and Liouville's theorem. Fixed points, stability, attractors, bifurcations. Strange attractor, aperiodicity and predictability in simple chaotic systems, Lyapunov exponents.

Convective instability, Rayleigh-Bénard convection. Lorenz system as a simple model of Rayleigh-Bénard convection. Simple scaling arguments for turbulence.

Simple stochastic processes, Einstein's theory of Brownian motion as an example of the fluctuation-dissipation theorem. Random walk, diffusion equation.

Examples of stochastic processes in biology: fluctuations and gene expression; molecular machines for active transport, the freely-jointed chain model of the mechanical properties of biopolymers. Biophysical single-molecule measurements.

B2. Symmetry & relativity

Transformation properties of vectors in Newtonian and relativistic mechanics; 4-vectors; proper time; invariants. Doppler effect, aberration. Force and simple motion problems. Conservation of energy-momentum; collisions. Annihilation, decay and formation; centre of momentum frame. Compton scattering.

Transformation of electromagnetic fields; the fields of a uniformly moving charge. 4-gradient.The electromagnetic potential as a four-vector; gauge invariance, the use of retarded potentials to solve Maxwell's equations (derivation of functional forms of potentials not required).

Equations of particle motion from the Lagrangian; motion of a charged particle in an electromagnetic field.

Field of an accelerated charge; qualitative understanding of its derivation; radiated power, Larmor's formula. The half-wave electric dipole antenna.

3-d and 4-d tensors; polar and axial vectors; angular momentum; the Maxwell field tensor $F_{\mu\nu}$; Lorentz transformation of tensors with application to E and B. Energy-momentum tensor of the electromagnetic field, applications with simple geometries (e.g. parallel-plate capacitor, long straight solenoid, plane wave).

2-spinors: rotation, Lorentz transformation and parity; classical Klein-Gordon equation [*Non-examinable: Weyl equations; Dirac equation.]*

B3. Quantum, atomic and molecular physics

Multi-electron atoms and the central field approximation. Electron configurations, shell structure and the Periodic Table. Atoms with 1 or 2 valence electrons. Residual electrostatic interaction, singlet and triplet terms, LS-coupling. Spin-orbit interaction (fine structure).

Simple ideas of atomic spectra and energy levels. Term symbols. Selection rules for electric dipole radiation. Magnetic dipole hyperfine structure; weak and strong magnetic field phenomena in both fine and hyperfine structure. Inner shell transitions and X-ray notation, Auger transitions.

Basic ideas of molecular physics, Born-Oppenheimer approximation, vibrational (simple harmonic oscillator) and rotational (rigid rotor) energy levels for heteronuclear diatomics.

Two-level system in a classical light field: coherent light and Rabi oscillations. Einstein A&B coefficients and thermal radiation. Decaying states and Lorentzian lineshape, incoherent light and rate equations. Homogeneous and inhomogeneous broadening of spectral lines.

Optical gain and absorption. Minimum conditions for laser operation, population inversion, 3- and 4-level laser systems. Specific intensity, the optical gain cross section, rate equations governing population inversion and growth of laser radiation. Saturated absorption and saturated gain.

B4. Sub-atomic Physics

Knowledge of the special relativity in the Prelims paper CP1 will be assumed

Concept of a scattering cross section, Quantum mechanical scattering; The Born approximation. Feynman rules in quantum mechanics. Yukawa potential, propagator, virtual particle exchange. Resonance scattering, Breit-Wigner; decay widths. Fermi's golden rule. Use of invariants in relativistic particle decay and formation.

Elastic and inelastic scattering; form factors. Structure of the nucleus: nuclear mass & binding energies; stability, radioactivity, α and β decay; Fermi theory, the (A,Z) plane; basic fission and fusion reactions (U-235 fission, proton- proton fusion).

Quark model of hadrons: the light meson and baryon multiplets; nucleons as bound states of quarks; quarkonium; the ratio of cross sections (e+e- to hadrons) to (e+e- to muons); phenomenology of deep inelastic scattering.

The Standard Model: quark and lepton families, fundamental interactions and flavour mixing. The strong interaction and qualitative discussion of confinement. Weak interaction, parity violation, Cabibbo mixing, properties and decays of W and Z boson. The width of the Z and the number of neutrino types.

B5. General relativity and cosmology

Newtonian gravity, examples of two body and spherical configurations; Gravitational and inertial mass; the Einstein equivalence principle.

Accelerating frames, metrics, covariant derivatives and the geodesic equation; connection between metric and the Newtonian potential; the Newtonian limit. *[Non examinable: GPS.]*

Gravity and light: gravitational redshift, deflection of light, lensing. Curvature of spacetime; the curvature tensor; Ricci tensor and scalar.

Einstein field equations: the Einstein tensor, symmetries, the energy-momentum tensor, the conservation of energy, relation of curvature and energy; Poisson's equation in the Newtonian limit. Properties of the Schwarzschild metric.

Linearized gravity. Simple treatment of gravitational radiation.

Experimental tests of General Relativity: precession of perihelion of Mercury; binary pulsar. Homogeneous isotropic spacetimes, Friedmann equations, redshift, scale factor, luminosity distance.

The expanding universe: its contents and energy-momentum tensor. Closed and open universes.

Cosmological distance ladder; Hubble constant; deceleration and acceleration; observational evidence for acceleration from high-z supernovae.

Thermal history of the universe. Formation of the CMB; decoupling between photons and baryons; cosmological parameters from CMB observations; formation of the light elements.

B6. Condensed-matter physics

Structure and types of condensed matter. Bonding of atoms: ionic, covalent, van der Waals, metallic *[Non examinable: hydrogen bonding].*

Introduction to crystals; lattice, basis, Bravais lattices, unit cell (primitive and conventional), Wigner–Seitz cell, crystal systems, lattice planes, interplanar spacing, crystal directions, Miller indices. Reciprocal lattice, reciprocal lattice vectors, Brillouin zones (in 1-, 2- and 3- dimensions). (Crystal systems with orthogonal conventional axes only).

Diffraction including Bragg and Laue equations, structure factor, systematic absences, atomic form factor and nuclear scattering length. Neutron and x-ray diffraction.

Normal mode dispersion for monatomic and diatomic linear chains (harmonic approximation, nearest neighbours only), acoustic and optic modes, group velocity. Born von Karman boundary conditions, density of states (in 1-, 2- and 3- dimensions). Lattice quantization, phonons. Lattice heat capacity, Einstein and Debye models. Elasticity and thermal expansion (simple case of anharmonic oscillator only).

The free-electron theory of metals. Electron density of states, Fermi energy, Fermi surface. Electrical conductivity and Ohm's law. Electronic heat capacity of metals. Experimental determination of electron mobility and mean free path in a metal (from carrier density and conductivity), and density of states at the Fermi level (heat capacity). Second-order non-degenerate and first-order degenerate perturbation theory to model 1-dimensional electron dispersion in the presence of a weak periodic potential. Tight binding model (1-dimensional treatment only). Band gaps. Qualitative generalisation to 2- and 3- dimensions. The distinction between metals, semiconductors and insulators.

Direct and indirect gap semiconductors, band structures near the band edges in Si, Ge and GaAs. Optical absorption, effective mass, holes. Temperature dependence of carrier concentration (parabolic bands only), law of mass action. Impurity binding energy, thermal ionisation of donors and acceptors. Mobility and Hall effect in systems with one dominant carrier type. Experiments that determine the band gap (temperature dependence of conductivity or Hall resistance), direct band gap (optical absorption), sign and concentration of the majority carrier (Hall effect), and mobility of the majority carrier (Hall resistance and conductivity). *[Non-Examinable: Semiconductor devices, including p-n junction and transistor]*

Magnetic susceptibility, diamagnetism (descriptive treatment only), application of Hund's rules to determination of magnetic ground states of isolated ions, paramagnetism of isolated atoms/ions (temperature dependence of magnetization, Curie's law), Pauli paramagnetism. Magnetic ordering . Weiss molecular field theory of ferromagnetism, Curie temperature, Curie–Weiss susceptibility, exchange interactions. Ferromagnetic domains, domain (Bloch) walls. *[Non-examinable: antiferromagnetism, ferrimagnetism, itinerant ferromagnetism, Hubbard model].*

S01. Functions of a complex variable

Complex differentiation and definition of analytic functions, Cauchy-Riemann equations, orthogonal families of curves and complex mapping, conformal transformations and applications.

Complex integration, Cauchy's integral theorem and integral formula, Taylor series, isolated singularities and Laurent series, residue theorem and evaluation of real integrals, Jordan's lemma and other types of integral, branch points, branch cuts and Riemann surfaces, integration with cuts or with removable singularities, other selected applications of complex calculus.

S07. Classical Mechanics*

Calculus of variations: Euler--Lagrange equation, variation subject to constraints.

Lagrangian mechanics: principle of least action; generalized co-ordinates; configuration space. Application to motion in strange co-ordinate systems, particle in an electromagnetic field, normal nodes, rigid bodies. Noether's theorem and conservation laws.

Hamiltonian mechanics: Legendre transform; Hamilton's equations; examples; principle of least action again; Liouville's theorem; Poisson brackets; symmetries and conservation laws; canonical transformations.

[Non-examinable: Hamilton--*Jacobi equation; optico-mechanical analogy and derivation of Hamilton's principle from path integral. Action-angle variables.]*

***Note: the above S7. Classical Mechanics syllabus is also that for B7. Classical Mechanics, the Physics and Philosophy paper but includes the non-examinable material.**

S10. Medical Imaging and Radiation Therapy

The physics that is applied in imaging, diagnostics, therapy and analysis in medicine: Interaction of X-rays with matter (Photoelectric, Compton, Pair Production); X-ray imaging (scintillation and diode detection) and Computed Tomography; Magnetic resonance fundamentals, basic imaging & slice selection, functional imaging (diffusion-weighted imaging, dynamic contrast-enhanced imaging, spectroscopy); Ultrasound and its application to imaging, including Doppler imaging; Use of radioisotopes: Gamma cameras, SPECT, PET & radionuclide therapy; Radiotherapy: microwave linacs, bremsstrahlung, beam collimation, portal imaging; Introduction to radiotherapy planning: CT simulation, conformal therapy, IMRT, charged particle therapy; Radiation Dosimetry (ionisation chambers, film, diodes, TLDs); Safety considerations; Comparisons between imaging methods.

S12. Introduction to Biological Physics

Introduction to biological molecules, the structures and processes of life: organisms, organs, cells, molecules and molecular machines. DNA and RNA; the double helix, the "central dogma" and DNA code, DNA processing in cells, genes, inheritance. Proteins; the importance of water, amino acids and their properties, forces in protein folding, primary, secondary, tertiary and quaternary structure, methods of structure determination, proteins as catalysts and machines. Lipid bilayer membranes; self-assembly of lipids, vesicles, electrical properties, ionic solutions and Nernst potential. Biological membranes; ion channels and other membrane proteins.

Proteins as nanotechnology: importance of thermal energy, selfassembly, examples of protein nano-machines.

S14. History of Physics

Medieval natural philosophy: the basic Aristotelian scientific views that dominated learned thought until the Seventeenth Century, and why the system became increasingly implausible by the end of the Sixteenth Century.

The instrumental origins of the Scientific Revolution: how in the first three decades of the Seventeenth Century there was a transformation in the way that researchers understood nature, such that for the first time it became conceivable that experiments and scientific instruments could give improved evidence about the natural world.

The Mathematization of Nature: the introduction by Galileo and Newton of new and immensely powerful mathematical approaches to nature, the ways in which they argued for these approaches and the response to them.

The Evidential Basis of the Newtonian system: the experimental and observational corroboration of the Newtonian system in the Eighteenth Century, including the shape of the Earth, the prediction of the return of Halley's comet in 1759, and the triumph of celestial mechanics.

Electromagnetism from Oersted to Maxwell: the work of Oersted, Faraday, Maxwell and Heaviside, and resulting contemporary technological innovations.

Carnot's Inheritance and the Creation of Thermodynamics: Carnot's analysis of Watt engines, his idealisation of a perfect engine by means of the Carnot cycle, and the later work of Joule, William Thomson, and Clausius leading to the concept of energy.

Small Particles and Big Physics from Marie Curie to CERN: the twentieth century elaboration of the structure of matter, from the pioneering work of Wilson, JJ Thomson, and Rutherford, the work of Marie and Pierre Curie, Moseley's use of X-Ray spectroscopy to demonstrate the physical foundation of the Periodic Table, to the beginnings of particle physics

Einstein's Universe: Finding Evidence for the General Theory of Relativity from Eddington to LIGO.

S16. Plasma Physics

Saha Equation. Heat Capacity of a Plasma. Debye Length.

Plasma frequency. The plasma parameter and 'good' plasmas. Single particle motion: Larmor orbits, guiding centre drift, drift of particles in electric and gravitational fields, grad-B drift. First adiabatic invariant. Analysis of subset of electrostatic and electromagnetic waves in unmagnetized and magnetized cold plasmas. Coronal Equilibrium. Plasma dispersion and Faraday Rotation and application to simple astrophysical problems.

Concept of collisionless plasmas and collective effects. Collision times and the Coulomb Logarithm. The fluid approximation, Bohm-Gross frequency. The Vlasov equation and Landau damping (integration in the complex plane not required). The Lawson criterion. Simple concepts of magnetic confinement fusion. Inverse bremsstrahlung absorption.

Rayleigh-Taylor Instability and simple concepts of inertial confinement fusion.

S25. Physics of Climate Change

This course outlines the basic physics underlying our understanding of how the global climate system responds to increasing greenhouse gas levels and its implications for the future. We cover: the distinction between weather and climate in a chaotic system; planetary energy balance; atmospheric temperature structure and its role in the greenhouse effect; forcing, feedbacks and climate sensitivity; the role of the oceans in the transient climate response; the global carbon cycle; simple coupled ODE models of global climate change; how we use observed climate change to quantify what is causing it and to constrain climate projections; simple climate change economics, including the principles and pitfalls of benefit-cost maximisation; and the prospects and risks of geo-engineering. In addition to the lectures, participants will be asked to undertake a small-group exercise using a simple (Excel-based) Integrated Assessment Model, devise their own global climate policy and defend it to the rest of the class.

S30. Exoplanets

Overview of the main planet detection methods: radial velocities (Keplerian orbits and the radial velocity equation, spectroscopy and Doppler shift measurement basics), transits (basics of stellar photometry, unique solution of transit light curve), astrometry (astronomical distance and angular scales, astronomical coordinate systems, parallax and proper motion), direct imaging (blackbody emission, planetary albedo, expected contrast, spatial resolution of ground-based telescopes and the concept of seeing, basics of adaptive optics and coronography), and microlensing (microlensing equation, probability of microlensing event, timescale for planetary microlensing signals). Comparison of the biases and limitations of the different techniques, key instruments/missions at present and in medium term future.

Formation, dynamics and statistics: standard model of star formation, accretion discs basics, introduction to planet formation models (core accretion / gravitational instability). Torque exerted by the disk on the planet (planet migration). Star-planet interaction (tides). Overview of statistics of the exoplanet population (mass, semi-major axis, eccentricity and radius distribution, properties of the host stars) and comparison to theoretical expectations.

Evolution and atmospheres: evolution of a pure H/He sphere in the absence of heat source. Energy budgets and mass-radius relation for different kinds of planets, qualitative introduction to the effect of external heating (stellar irradiation). Hydrostatic equilibrium, atmospheric scale height, key constituents of planetary atmospheres, key features of atmospheric spectra. Effects of small particles (Rayleigh scattering). Habitable zone: definition, location for different star types. Biosignatures: notion of chemical (dis-) equilibrium, techniques and prospects for detection of extraterrestrial life.

S31. Numerical Methods

Types of partial differential equations (elliptical, hyperbolic, parabolic); finite difference approximations for partial differential equations: discretization on a grid, Taylor series and accuracy of discretization, stability analysis of linear PDEs (one-dimensional heat conduction equation, scalar advection equation), physical meaning of stability criterion.

Collisionless N-body dynamics: Poisson-Vlasov system; Monte-Carlo approach to N-body dynamics; Time integration schemes for advancing positions and velocities of particles (e.g. explicit Euler method, Runge-Kutta methods, leapfrog method); symplectic integration schemes; gravitational force calculation: direct summation, particle mesh methods (mass assignment schemes, Fourier methods, relaxation solvers), tree algorithms.

Lagrangian versus Eulerian hydrodynamics; Smooth Particle Hydrodynamics: kernel interpolation; constructing derivatives from discrete tracer points; basic equations of smooth particle hydrodynamics; artificial viscosity and shock capturing.

Grid-based hydrodynamics: Euler equations as a set of hyperbolic conservation laws; conservative versus primitive variables; solution to linearized Euler equations and Riemann problem; solving non-linear conservation laws: shocks and rarefaction waves.

Appendix D Complaints and Appeals

Complaints and academic appeals within the Department of Physics

The University, the **MPLS Division** and **Department of Physics** 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 **Department of Physics**, then you should raise it with the Head of Teaching, **Prof Hans Kraus**. Complaints about departmental facilities should be made to the Head of Administration, **Mrs Nicola Small**. If you feel unable to approach one of those individuals, you may contact the Head of Department, **Prof Ian Shipsey**. 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).