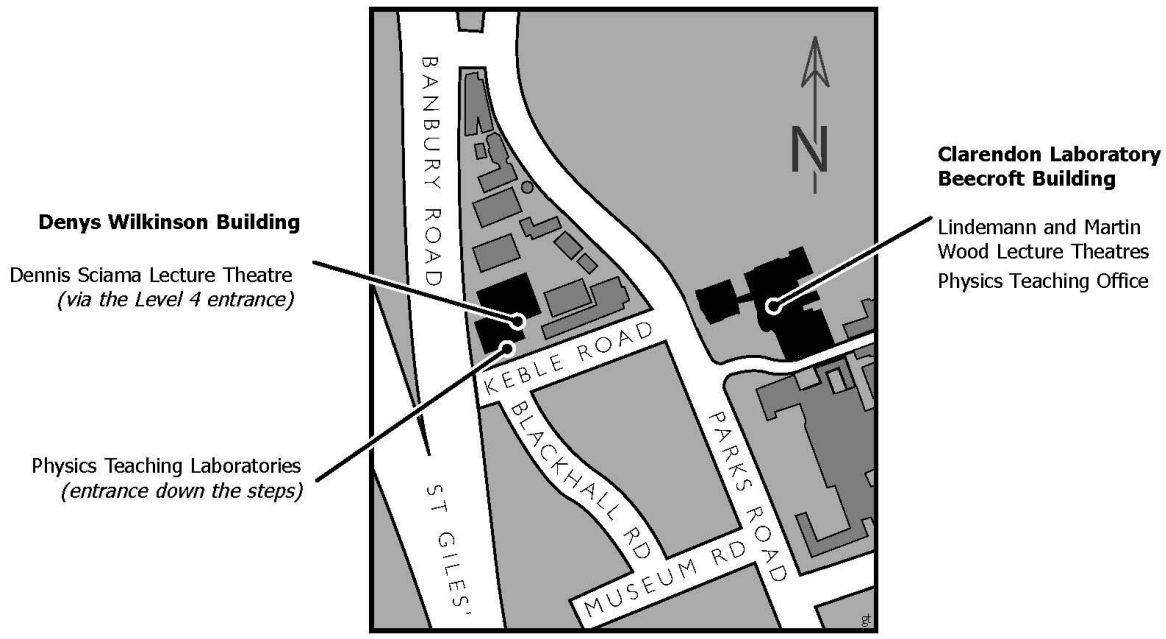
Physics Undergraduate Course Handbook 2021-2022

Third Year (Part B)



Map of the Department of Physics Buildings



Useful Department Contacts

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Disability Contact	Mrs C Leonard-McIntyre carrie.leonard-mcintyre@physics.ox.ac.uk	72407
Teaching Laboratory Manager	Dr J Barnes jenny.barnes@physics.ox.ac.uk	73491
Teaching Office Administration Officer	Miss H Glanville hannah.glanville@physics.ox.ac.uk	72369
Teaching Office e-mail address	teachingadmin@physics.ox.ac.uk	
Teaching lab support	labhelp@physics.ox.ac.uk	
PJCC Website	https://pjcc.physics.ox.ac.uk/	

These notes have been produced by the **Department of Physics**. The information in this handbook is for the academic year Michaelmas Term 2021, Hilary Term 2022 and Trinity Term 2022.

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Course Information Updates

The University publishes updates at https://www.ox.ac.uk/coronavirus. Adaptations to the physics undergraduate course, may be necessary due to, e.g. the Coronavirus (Covid) etc. and will be derived from the university guidance and be published on Canvas.

Introduction to the handbook

A handbook is provided for each year of the programme and it is also useful to read the handbooks on topics available in later years. This handbook contains, amongst other things, a comprehensive book/reading list, also available via ORLO (Oxford Reading List Online); 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 this handbook and in the Part B Practicals course on Canvas.

Course handbooks: Please refer to the *Physics and Philosophy Course Handbook* for all details of the Physics and Philosophy course that are not covered in the *Physics Undergraduate Course Handbook*.

Undergraduate course information is available at Physics undergraduate Degree for particular information about college teaching, students should contact their tutors.

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

For full and up-to-date lecture information, see lecture timetables.

The examination times given in this handbook are based on information available in September 2021. These may change and the definitive times are those published by the examiners on the official examiners' page.

The Examination Regulations relating to this course are available at https://examregs.admin.ox.ac.uk/. 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 by e-mail at teachingadmin@physics.ox.ac.uk.

The information in this handbook is accurate as at **6 October 2021**, however it may be necessary for changes to be made in certain circumstances, these will be published. 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 2	Introduction to Industrial Projects	09:00	***
Week 1	Project Safety for BA students	***	
Week 2	Short Options: S20; S21; S27 and S28		
Week 4	Application for more practical work, vacation placement and alternative subjects deadline		
Week 8	Entry for Part B	Fri	*

Hilary Term	Event	Time	Location
Week 4	Industrial Project Presentations	***	***

Trinity Term	Event	Time	Location
Week 1	Hand in BA projects	Mon 12:00	Online submission
Weeks 1- 4	Assessed Practicals	Mon/Tues	To be confirmed
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	Online submission
Week 6	Mini-project marks from college tutors to Teaching Office for examiners	Fri	
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. We recommend that all students obtain use of a computer, either their own personal laptop or use of a college computer.

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 at: 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 Office 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 Turnitin. Copying sources (e.g. Wikipedia) word for word will not be accepted, unless speech marks are used around a very short extract from the source and the source is correctly referenced.

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 2017-18.]

"If you have a disability and have not already been in touch with Disability Advisory Service **(**DAS) we strongly recommend you to contact them to discuss what support and/or adjustments may be appropriate for you. Agreeing a Student Support Plan (SSP) with DAS is an essential step to ensuring that you get whatever reasonable adjustments, advice and assistance you may need to give you the best experience and benefit from your time at the University." [Ref: Student Handbook 2021-22.]

The *Examination Regulations* provide guidance for students with special examination needs, see http://www.admin.ox.ac.uk/examregs/ for more information. The Disability Contact for the Department, is the Assistant Head of Teaching.

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

Employability and careers information and advice

The University Careers Service (at 56 Banbury Road) provides careers advice for both undergraduates and graduates. 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. Feedback is 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 https://www.thestudentsurvey.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 https://www.oxfordsu.org/ 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. See https://www.iop.org/ for more information.

Third Year 2021-2022

Introduction to the Third Year

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

Aims and Objectives

The first year handbook contains an overview of the course intentions, and includes information about subject benchmark statements, the split of Department and College teaching, expectations of study and workload etc. Please 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, third year students must make the decision which course to take either the three year course (BA) or the four year course (MPhys). Uncertain about which course to take, please talk to their college tutors about making this decision. The four year course is designed to be challenging and will involve an appreciable amount of advanced work. Stdents will also be expected to work more independently in the fourth year of the MPhys course in comparison to the first three years.

Changing from the MPhys to the BA (**before** 1st week MT)

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

Changing from the MPhys to the BA (**after** 1st week MT)

If you want to change to the BA after the deadline of **Friday noon of 1st week,** you can only exit after publication of the Part B results, normally in July.

Exiting the MPhys course with a BA degree

During your 3rd year **and** after the publication of your 3rd year, Part B results, you may wish to leave the MPhys course. The Year Outcome (Classification) is included in each MPhys Part B candidate's student record. This information is intended to assist any MPhys candidate who is considering withdrawing with a BA degree or transferring to the MMathPhys after the Part B results have been released.

It is important that you discuss this decision with your college tutors in the first instance and inform the Assistant Head of Teaching.

The procedure for the BA exit route is: The student informs their College, normally the Academic or Tutorial College Office, that it is their intention to leave the MPhys 4-year course after year 3 with a BA as this is the mechanism to graduate after completion of year on the MPhys course.

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. In the *Examination Regulations "*(5) A candidate who has satisfied the requirements for Part A and Part B of the four-year course, but who does not start or enter Part C or who fails to obtain Honours in Part C is permitted to supplicate for the Degree of Bachelor of Arts in Physics (Pass, or Honours with the classification obtained in Parts A and B together, as appropriate); provided that no such candidate may later enter or re-enter the Part C year, or supplicate for the degree of Master of Physics; and provided in each case that the candidate has fulfilled all the conditions for admission to a degree of the University." at www.admin.ox.ac.uk/examregs/

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

Practical Work

Aims of Practical Work

As in Prelims and Part A, the major aim of practical work is to train you in the basic skills of experimental physics. More specifically, we intend that you learn how to carry out (and ultimately design) experiments and to appreciate the contribution that experimentalists make to the subject.

Thus, our aims are to enable you to:

- see, investigate and understand some of the important phenomena in physics
- become familiar with the basic scientific method
- become familiar with commonly used instrumentation and measurements in physics
- become familiar with the skills required for experimental work such as data acquisition, data analysis and computer programming
- learn how to clearly document your work in a logbook
- learn how to analyse experimental data
- learn how to present your work clearly, both orally and in writing
- learn about safe working practice
- learn how to design and develop experiments.

The examiners' requirement for practical work for Part B is **6** days (regular practicals) + **4** days (mini project), but note that your SPIRe lab record will only show 8 days (6 days + 2 days of credit for the regular practical part of mini-project). Two further days of practical work will be added to your final exam results for the mini project write up.

It is possible to substitute 6 days of extra practical work for a short option.

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 Examination Conventions 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 8 days. The allocation for the mini project is given below (this is the nominal allocation, please check your record on SPIRe for your group allocation):

Weeks	Groups	Colleges
MT 1-2	A,B	Mansfield, Merton, St John's, Pembroke Balliol, Brasenose, Exeter, Magdalen
MT 3-4	C,D	Queens, SEH, Wadham Jesus, St Catherine's, Worcester
MT 5-6	E,F	New, Somerville, St Anne's, St Peter's Christ Church, LMH, Oriel, Trinity
MT 7-8	G,H	Hertford, Corpus, St Hilda's St Hugh's, Keble, Lincoln, University

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. **The deadline for colleges to provide mini-projects marks to the Teaching Office is Friday of 6th week in 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. One Short Option must be offered in Part B.

Short Options offered by other departments of faculties

(a) Language Options

A course is offered in French, German and Spanish every year [*A change from previous years when Spanish and German alternated*]. Students need to have some prior knowledge of the language and will need to take a preliminary online language level evaluation test to ascertain their current level and be placed in a suitable Fast Track course. The minimum entry requirement is normally an A at GCSE in the relevant language (or equivalent).

The language options will be taught over two terms in Hilary and Trinity Terms. The courses will involve 32 hours (2 hours a week in Hilary and Trinity Terms) of classes together with associated work. It can be used to replace the Short Option paper.

Specific details about the Language Centre presentation arrangements will be circulated to students in Michaelmas Term by e-mail.

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 (or German) in their third year, subject to eligibility.

(b) Pre-approved Alternative Subjects

Several alternative subjects that have been pre-approved and are offered by other faculties or departments can be studied in place of one short option. These are:

(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

In the third year, students can choose:
1. S20: History of Science can be offered as one short option or
2. S21: Philosophy of Physics can be offered as one short option.

Students wanting to do any of the above **must enrol** for the short option(s) and/or paper with students indicating how they would prefer to attend tutorials **online** or **in-person**, see https://oxford.onlinesurveys.ac.uk/history-and-philosophy-of-science-short-option-signup-mt by **12 noon** on the **Friday of 1st week**.

(ii) S27: Philosophy of Space-Time and S28: Philosophy of Quantum Mechanics are offered by the Philosophy Faculty. These short options 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 by e-mail at teachingadmin@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 implication 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.

(c) Alternative Subjects

Students may request to substitute their 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.

Students must provide precise details of the subjects (courses) and/or topics 'the electronic links to those courses and the examination paper(s). Everything about the proposed course(s) - i.e. the number of lectures and/or classes etc. will be considered.

These necessary requirements have to be met:

- Approval of the other department (e.g. MMathPhys coordinator)
- Approval of your college
- Approval of the Head of Teaching

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.

Application must be made via the Assistant Head of Teaching by e-mail to teachingadmin@physics.ox.ac.uk to replace the compulsory Short Option paper in Part B; the **deadline is Friday of 4th week Michaelmas Term**.

Students will be notified formally of the outcome decision of their application by e-mail as soon as possible **after** 4th week of Michaelmas Term.

The assessment mark provided by the other department will be used directly by the Examiners.

More practical work instead of a short option

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 labhelp@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 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 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 an electronic copy (by e-mail attachment) of their report to the Physics Teaching 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.

- Your work must be identified **only** by your candidate number (which can be found by visiting Student Self-Service). Your candidate number does NOT appear on your University card.

- Your **report** should not contain any other pieces of information that could identify you to the marker of your paper.
- The file name should follow the format: *Candidate number*_Report Title e.g. 1234457_My Ideal Practical.

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 SPIRe as usual. **If you have done six additional days of practicals in Part A you 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 labhelp@physics.ox.ac.uk once you have decided which area of physics you would like to work in. Students must submit an electronic copy (by e-mail attachment to labhelp@physics.ox.ac.uk) of their report to the Physics Teaching 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.

- Your work must be identified **only** by your candidate number (which can be found by visiting Student Self-Service). Your candidate number does NOT appear on your University card.
- Your **report** should not contain any other pieces of information that could identify you to the marker of your paper.
- The file name should follow the format: *Candidate number*_Report Title e.g. 1234457_My Ideal Practical.

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

Substituting practical work with vacation placements

It is possible to replace some of the practical quota by a report on Physics-related vacation placements.

Vacation placements

Work carried out during a vacation placement may be submitted for practical course credit. Students wanting to gain credit for vacation work must apply for approval via labhelp@physics.ox.ac.uk after the placement by returning the form AD12. All applications for project substitution for practical work in Michaelmas term must be received before noon on Friday of 4th week of Michaelmas Term. The outcome of these applications will be communicated by e-mail. 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 Part B Practicals Canvas course.

Textbooks

A list of the books recommended by the lecturers is given in **Appendix A** and is also available via ORLO (Oxford Reading List Online). Your tutor will advise you as to what books you should obtain.

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.

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 by e-mail to teachingadmin@physics.ox.ac.uk in Trinity Term of your **third** year.

Students will need to provide precise details of the subjects (courses) and/or topics 'the electronic links to those courses and the examination paper(s). Everything about the proposed course(s) - i.e. the number of lectures and/or classes etc. will be considered. **The alternate subjects for Major Options have to be approved by the Physics Academic Committee, so the outcome of these applications are normally only given after the first meeting of this committee, 1st week, of Michaelmas Term**.

Students will be notified formally of the outcome of the application by e-mail after all the necessary requirements have been met:

- Approval of the other department (e.g. MMathPhys coordinator)
- Approval of your college
- Approval of the Head of Teaching

The assessment mark provided by the other department will be used directly by the Examiners.

Fourth Year (MPhys) projects

The *MPhys Projects Trinity Term* handbook published at https://canvas.ox.ac.uk/courses/67877/modules/items/1255132 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.

Physics and Philosophy

The physics component consists of **two** (or **four** if your elective paper is in physics) subjects drawn from the following list: **B1** Fluids; **B2** Symmetry and Relativity; **B3** Atomic and Laser Physics; **B4** Nuclear and Particle Physics; **B5** General Relativity; **B6** Condensed Matter Physics; **B7** Classical Mechanics; **B8** Computational Project; **B9** Experimental Project.

Physics and Philosophy students **must choose** at least two of subjects B2, B5, and B7.

Papers B1-B7 are the same as the core Part B physics papers taken by MPhys students, which are examined in six 2-hour papers. The B7 paper is specially set for P&P students, in the same format as the other physics papers 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 or project.

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

The table below indicates the BA and MPhys course structures.

	MPhys			**BA**		
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
B4+B6	2	2	2	2	2	2
B1,B2,B3,B5	3	2	1	1	2	1
B8, B9 (projects)		1	2	2	1	
Industrial Project						✓
Short option	✓	✓	✓	✓	✓	✓
Practical work	✓	✓	✓	✓	✓	✓
Mini-project	✓	✓	✓	✓	✓	✓

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 Fluids	HT	24	~ 5
	TT	2	
B2 Symmetry and Relativity	MT	24	~ 5
	TT	2	
B3 Atomic and Laser Physics	HT	24	~ 5
	TT	2	
B4 Nuclear and Particle Physics	MT	24	~ 5
	TT	2	
B5 General Relativity	HT	24	~ 5
	TT	2	
B6 Condensed Matter Physics	MT	24	~ 5
	TT	2	
B7 Classical Mechanics (MPhysPhil)	HT	12	
	TT	2	
B8 Computational Project	MT	4	
	HT		
B9 Experimental Project	MT	4	
	HT		
Additional lectures	MT	3	
	HT	1	
	TT	3	
S01. Functions of a Complex Variable	TT	12	
S04. Energy Studies	TT	12	
S07. Classical Mechanics	HT	12	
S12: Introduction to Biological Physics	TT	12	
S14. History of Physics	MT	8	
S16. Plasma Physics	TT	12	
S18. Advanced Quantum Mechanics	HT	12	
S20. History of Science	MT	8	
S21. Philosophy of Science	HT	16	
S22. Language Options	HT & TT	2(3) hours per week	
S26. Stars and Galaxies	TT	12	
S27. Philosophy of Space-Time	MT	16	
S28. Philosophy of Quantum Mechanics	HT	16	
S31. Numerical Methods	TT	12	
S32. Chaos, Random Processes and Predictability	TT	12	
S33. Entrepreneurship for Physicists	TT	12	
S34. From Signals to Data	TT	12	

Practical Work

Most of the information you require for the practicals can be found online on the Part B Practicals pages on Canvas (www.canvas.ox.ac.uk). The information here details some of the most important information but you must also study the pages on Canvas as well.

Organisation

For the academic year 2021-22, Part B students are able to book in person and remote experiments on Mondays and Tuesdays every other week. Your allocated weeks and labs will be shown on your page of SPIRe (the Student Practical Information Record). In Michaelmas term, non mini project experiments will be available in weeks 1-8 and also in Trinity Term weeks 1-4. Mini project experiments are only available in weeks 1-8 of Michaelmas Term. You are free to do experiments from any lab; there are no compulsory experiments. Bookings are made on a first come, first served basis.

Practical work timetable: Labs are open 1000-1700 (10am-5pm)

Term	Part B
Michaelmas	All practicals (and mini project) weeks 2-8
Hilary	No labs or marking (unless by appointment)
Trinity	All practicals (and assessed practical) weeks 1-4

Laboratories are staffed by demonstrators. Demonstrators are university staff or postgraduate students who are there to help you with the experiments. They provide advice and assistance whilst you are doing the experiment and will assess your performance. If you are in doubt about any aspect of the experiment, ask a demonstrator. The lab technicians have an engineering knowledge of the experiments and will help set up and fix equipment.

At the beginning of the academic year, students are allocated to the different laboratories on a rota system. SPIRe will show your allocation and you can only book experiments within your allocation. It is possible to work out of allocation (i.e. at a time not offered to you by SPIRe), though not to book. If you must work at a different time to your allocated slot it is recommended you contact labhelp@physics.ox.ac.uk for advice. **Please pre-book all experiments before turning up to the labs– if you are not able to pre-book and are interested in what practicals might be available each week, please email labhelp@physics.ox.ac.uk or look out for announcements on Canvas.**

To fulfil the practical work requirements for the third year (Part B) you must complete eight days of practical work (usually three two-day practicals plus a mini-project). The mini-project that you write up in college does not get any credit on your SPIRe lab record, but everyone who completes a mini project write up gets an extra two days of lab credit added to their record at the examination stage, so your transcript will eventually show that 10 days of practical work were completed. You must complete the following days of practicals:

A completed experiment is one that has been carried out, assessed as satisfactory by a demonstrator, and the grade entered in your computer record on SPIRe (the Student Practical Information Record). Your computer record can be examined by your tutor(s) at any time, and reports on your progress are regularly sent to tutors.

You should prepare for the experiments you choose by obtaining and reading its instructions, called a "script", in advance (available from SPIRe and Canvas). Scripts may also contain additional explanation or theory (in Electronics the background material is in a separate manual). You must decide in advance which experiment you intend to do next and book it. ***Demonstrators may ask you to leave if you do not show adequate knowledge of the practical at the start of the session.***

After you have completed the practical you must ensure that it is marked and that your computerised mark record on SPIRe is kept up to date. You must meet the deadlines for the practical work as detailed in this handbook and online on the Part B Practical pages on Canvas. If you think your record is incorrect, please email labhelp@physics.ox.ac.uk with details of the issue.

You work in pairs in all labs except Astrophysics and the regular 2 day practical AP03 in the Atmos lab, but reports are always written individually. Your practical partner is usually from the same college as you but it is possible to change lab partners; SPIRe has details on how to do this. For 2021-22, please try and stay with the same lab partner for the year if possible. Please note:

- Both practical partners should be simultaneously present throughout the lab, i.e. logbooks cannot be copied up by an absent partner retrospectively. Partners should synchronise their breaks.
- If one member of a pair is absent for more than an hour without giving prior notice, leaving one person to do the experiment alone, it will be assumed they have withdrawn from the assessment, and a mark of 0 will be given to the absent student.

Unavoidable absences of one partner (e.g. a medical appointment, job interview) should be discussed with the demonstrators well before (e.g. the previous week) starting the experiment. It is often possible to rearrange - email labhelp@physics.ox.ac.uk for assistance with rearrangements. The Frequently Asked Questions page on the Part B Practicals Canvas course explains how to deal with common issues, such as what to do if you are unwell.

Assessment

Your practical work is assessed in several ways. Demonstrators will observe your work and inspect the records in your logbook during the experiment. It is important to be able to present your scientific results clearly, as several write-ups are required. Training in written presentation of your work has been provided by the writing of Part A Computing reports assessed by demonstrators.

Demonstrators will visit your experiment regularly. They will

- discuss the experiment with you; you will need to show them that you understand the underlying physics
- check what you have been recording in your logbook
- check analysis of the data and the accompanying errors
- check that you have adequately summarised your experiment in writing.

If your record is satisfactory, the demonstrator will sign your logbook and write a comment on your progress so far. If changes need to be carried out (e.g. extra comments written in), the demonstrator will request that these are done before you continue. Analysis and plotting should be done as you go along unless you are instructed otherwise.

Summary of the experiment

When you have finished the experiment and data analysis, you should hand-write a brief (approximately half a page) summary of the work in your logbook. You should state the aims of the experiment, the method, and summarise the results and conclusions, quantitatively if possible. This is to both consolidate your understanding and to provide training in written skills. The ability to concisely report a piece of work by appropriate selection of material is an important skill both in physics and elsewhere. This should be written immediately after the experiment, but before marking.

Mark scheme

At the end of the experiment and a short discussion of your work, the demonstrator will then give you a mark. The criteria for each mark for practicals and reports is given in **Appendix D**. A mark of 0 or 1 shows an unacceptable level of understanding and you will be asked to do the experiment or report again. A mark of 2 is required to pass and obtain the credit for the practical. Once a student has a mark of 2 or higher, they cannot be re-marked for the same practical. The marks will be used to work out practical prizes at the end of the year. A demonstrator may refuse to mark an experiment which is presented more than three weeks after the booked lab time (ignoring vacations).

Assessed practical

The assessed practical is compulsory for all Part B Physics students. It is a short oral examination that takes place in Trinity Term.

You must write a short (1 page) report on a marked practical of your choice (not your mini-project or a vacation placement) and take it to a senior demonstrator, with your logbook, for assessment during lab classes in Trinity Term. The report is not marked, and is used to provoke discussion of your understanding of the experiment. The marking will be arranged informally by a sign-up sheet, similar to first year practical write ups. This is arranged on a first come first served basis, so if all slots for your chosen lab are full, then you will need to choose a different one. If you do not produce this write up for marking before the end of

the last lab session (Tuesday 1700hrs Week 4 Trinity Term) without good reason, you will get zero. Students must bring **all the logbooks they have used during Part B to the assessment.**

If you miss the assessed practical appointment without good reason you will lose marks.

The Part B Practical pages on Canvas (www.canvas.ox.ac.uk) have a variety of additional information including links to SPIRe and useful documents on, for example, experimental errors. A full list of the experiments in Part B can be found in **Appendix E.**

Physics 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**.

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.

Examination Dates

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

Examination Regulations

The regulations for the Final Honours School examinations are published in the *Examination Regulations* and are also published at www.admin.ox.ac.uk/examregs/.

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 official examiners' page.

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 https://www.ousu.org/ for the Student Union.

Past Exam Papers

Past examination papers and the data sheet are available at
https://canvas.ox.ac.uk/courses/67877/modules/items/738729

External Examiner and Examiners' Reports

The names of the External examiners are published in the Examination Conventions. Students are strictly prohibited from contacting external examiners and internal examiners directly.

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 official examiners' page explicitly forbid their use in the examinations. The calculators must conform to the rules set out at "Regulations for the Conduct of University Examinations: Part 10 Dictation of Papers,..., Calculators and the types of calculators which may be used in the Public examinations are in **Appendix B**.

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
Option 1: **Three** Written papers including B4, B6 and ***one*** other, from: B1,B2,B3,B5 **Two** Projects: B8 and B9 Short Option Paper Mini Project Practical Work	**Option 1:** **Five** Written papers including B4, B6 and ***three*** other, from: B1,B2,B3,B5 Short Option Paper Mini Project Practical Work	**Two** subjects in *Physics* and **Four** subjects in *Philosophy* *OR*
Option 2: **Four** Written papers including B4, B6 and ***two*** other, from: B1,B2,B3,B5 **One** Project: B8 or B9 Short Option Paper Mini Project Practical Work	**Option 2:** **Four** Written papers including B4, B6 and ***two*** other, from: B1,B2,B3,B5 **One** Project: B8 or B9 Short Option Paper Mini Project Practical Work	**Four** subjects in *Physics* and **Three** subjects in *Philosophy*. Physics and Philosophy students must choose at least ***two*** of subjects B2, B5, and B7
Option 3: **Three** Written papers including B4, B6 and ***one*** other, from: B1,B2,B3,B5 Industrial Project Industrial Group Presentation Short Option Paper Mini Project Practical Work	**Option 3:** **Three** Written papers including B4, B6 and ***one*** other, from: B1,B2,B3,B5 **Two** Projects: B8 and B9 Short Option Paper Mini Project Practical Work	

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**.

Marking Mini-projects

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

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.

The deadline for colleges to provide mini-projects marks to the Teaching Office is Friday 6th week in Trinity Term

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:

(i) A penalty of 5 marks will be deducted for each missed day of experiments.
(ii) If 6 or more days of experiments are missed, the Examiners may further penalise the student by lowering the final degree by one class.
(iii) If **no** experiments are completed, without good reason, the examiners can award a fail outcome for this part of the examination.

[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 by the student in advance for Part B) demonstrated by the student.

The precise details of how the practical marks are calculated are published in the Examination Conventions.

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 Part B Practicals Canvas course. Recommendations to the Finals examiners based on the awarded 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 on the Extra Practical Work page of the Part B Practicals Canvas course.

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.

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.

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 your year. 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.

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

Year Outcome for Part B

The examiners will classify students at the end of year 3 of the MPhys course according to 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

Part B Examination Prizes

Prizes may be awarded for excellence in various aspects of the third 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 https://canvas.ox.ac.uk/courses/67877/modules/items/1261517

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***

Third Year

B1 Fluids

'Physical Hydrodynamics', E. Guyon, J.-P. Hulin, L. Petit, C. D. Mitescu, 2nd edition, OUP, 2015**
'Elementary Fluid Dynamics', D. J. Acheson (OUP, 1990), ISBN-10: 019859679 **
'Fluid Mechanics', 2nd edition, Volume 6 of Course of Theoretical Physics, L. D. Landau, E. M. Lifshitz, (Elsevier) *
'An introduction to Fluid Dynamics', G. K. Batchelor, (Cambridge University Press *
'Physical Hydrodynamics', 2nd edition E. Guyon, J.–P. Hulin, L. Petit, C. D. Mitescu, (Oxford University Press) **
'Elementary Fluid Dynamics', D. J. Acheson, (Oxford University Press) **
'Fluid Mechanics', 2nd edition, Volume 6 of Course of Theoretical Physics , L. D. Landau, E. M. Lifshitz, (Elsevier) *
'An introduction to Fluid Dynamics', G. K. Batchelor, (Cambridge University Press *

B2 Symmetry and Relativity

Special Relativity
'Relativity made relatively easy', A. Steane (OUP) **
'Classical Electrodynamics', JD Jackson, (Wiley, 1998)*
'Introduction to Special Relativity', W Rindler, (OUP)
'An Introduction to Special Relativity and its applications', F N H Robinson, (World Scientific)

B3 Atomic and Laser 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' Hooker and Webb, ISBN13: 9780198506911, ISBN10: 0198506910 **
'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

B4 Nuclear and Particle 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

'General Relativity: An Introduction for Physicists', M. Hobson, G. Efstathiou and A. Lasenby (Cambridge, 2006)
'Gravitation,' C. Misner, K. Thorne, J. Wheeler (Princeton, 2017)
'Spacetime and Geometry,' S. Carroll (Cambridge, 2019)
'Gravitation and Cosmology', S. Weinberg (Wiley, 1972)
'Gravity: An introduction to Einstein's Theory of General Relativity', James Hartle (Addison-Wesley, 2003)
'Introduction to Cosmology,' B. Ryden (Cambridge, 2017)
'Black Holes, White Dwarfs, and Neutron Stars,' S. Shapiro and S. Teukolsky (Wiley, 1983)
(Cambridge, 2007)

B6 Condensed-Matter Physics

''The Oxford Solid State Basics', Steven H Simons (OUP, June 2013) ISBN-10: 0199680779 | ISBN-13: 978-0199680771 **
'Solid State Physics', N W Ashcroft and N D Mermin (Thomson Press, December 2003) *
'Introduction to Solid State Physics' C Kittel (Wiley, July 2018)
'Solid State Physics', H Ibach and H Luth (Springer, November 2009)

<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

S04. Energy Studies

'Energy Science', John Andrews and Nick Jelley (OUP 2013) **

'Renewable Energy Resources', Twidell & Weir (E&FN Spon)

'Energy', a guide book, J Ramage

Sustainable Energy- without hot air,' David MacKay, http://www.withouthotair.com/

'Elementary Climate Physics', F W Taylor, OUP

'Beyond Smoke and Mirrors', B. Richter, CUP

'Farewell Fossil Fuels – Reviewing America's Energy Policy', Borowitz

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**

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)

S18. Advanced Quantum Mechanics

"Quantum Mechanics", L.D.Landau and E.M.Lifshitz,(Pergamon Press, 1965)

"Advanced Quantum Mechanics", J.J.Sakurai, (Addison Wesley, 1967)

"Modern Quantum Mechanics", 2nd edition, J.J.Sakurai and J.J.Napolitano, (Addison Wesley, 2010)

"Intermediate Quantum Mechanics", H.Bethe and R.Jackiw, (Addison Wesley, 1986)

"Scattering Theory", J.Taylor, (Dover, 1972)

"Scattering Theory of Waves and Particles", R.Newton, (McGraw-Hill, 1966)

"Quantum Mechanics: Selected Topics", A.Perelomov and Ya.B.

S26. Stars and Galaxies

"Astrophysics for Physicists", Chouduri

"Galactic Dynamics", Binney & Tremaine

"An introduction to Modern Astrophysics" by B. W. Carroll & D. Ostlie (2nd edition Pearson/Addison Wesley 1987)

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)

S32. Random Processes and Predictability

Strogatz "Chaos" (MIT press)

S33. Entrepreneurship for Physicists

The Mom Test by Rob Fitzpatrick

Business Model Generation by Alexander Osterwalder

Mullins, John (2017) *The New Business Road Test*, Pearson 5th edition

Disciplined Entrepreneurship by Bill Aulet

S34. From Signals to Data

Paul Horowitz & Winfield Hill, The Art of Electronics, Cambridge University Press.

Mark Owen, Practical Signal Processing, Cambridge University Press.

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 https://examregs.admin.ox.ac.uk. The exact requirements in a given year will be published by the Examiners.

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 Fluids

Fundamental definitions, conservation principles.
Eulerian and Lagrangian descriptions.
Ideal fluids: Euler and vorticity equations, Bernoulli theorem (steady flow).
Surface waves: dispersion relation, group velocity, gravity-capillary waves.
Sound waves (linear treatment).
Potential flows, irrotational flow past an obstacle: complex potential, Kutta-Joukowski lift theorem.
Concept of stress in a continuous medium, stress-strain relationship.
Viscous flows: Navier-Stokes equation, no-slip condition, Reynolds number, examples of elementary viscous flows, dynamical similarity, very viscous flows.
Instabilities: Kelvin-Helmholtz, Rayleigh-Bénard, Rayleigh-Taylor; transition to turbulence.
Boundary layers: 2D laminar boundary layer equations, boundary layer separation.
Stratified fluids: buoyancy, internal gravity waves.

B2 Symmetry and Relativity

Concept of symmetry, groups and representations.
Examples of symmetries and applications.
Relativity in four-vector form and Lorentz transformations (Lorentz group), including Compton scattering and application to formation, collision, annihilation, and decay of particles.
Four-forces and simple motion problems.
Electromagnetism in four-vector and tensor formulation, including the Maxwell field tensor, the energy-momentum tensor of the electromagnetic fields, and their transformations.
Relativistic electrodynamics and radiation (field of an accelerated charge, retarded potentials, radiated power and Larmor's formula).
Concept of gauge invariance.

B3 Atomic and Laser Physics

Multi-electron atoms: central field approximation, electron configurations, shell structure, residual electrostatic interaction, spin orbit coupling (fine structure).

Spectra and energy levels: Term symbols, selection rules, X-ray notation, Auger transitions.
Hyperfine structure; effects of magnetic fields on fine and hyperfine structure.
Two level system in a classical light field: Rabi oscillations and Ramsey fringes, decaying states; Einstein A and B coefficients; homogeneous and inhomogeneous broadening of spectral lines; rate equations.
Optical absorption and gain: population inversion in 3- and 4-level systems; optical gain cross section; saturated absorption and gain.

B4 Nuclear and Particle Physics

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

Scattering in quantum mechanics to first order, concept of a scattering cross section, form factors, propagators, virtual particle exchange.
Resonant scattering, decay widths, Breit-Wigner formula.
Nuclear mass, binding energy, the semi-empirical mass formula, stability, radioactivity, alpha and beta decay.
Basic fission and fusion reactions.
Quark model of hadrons: the light meson and baryon multiplets and quarkonium.
The Standard Model: quark and lepton families, fundamental interactions, Cabibbo mixing.
Strong interaction, a qualitative discussion of confinement, the concept of colour.
Weak interaction, parity violation, properties and decays of the W and Z bosons.

B5 General Relativity

Gravity as a geometric concept, equivalence principle, tensor formulation of special relativity.
Gravitational redshift.
Tensor calculus, general covariance, affine connection, metric tensor, covariant derivatives. Newtonian limit/gravitational redshift connection. Parallel transport.
Geodesic motion in covariant form. Riemann and Ricci curvature tensors. Bianchi identities and Einstein Field Equations.
Classical tests of GR: light deflection, advance of Mercury's perihelion, Shapiro delay.
Black holes via Schwarzschild solution. Stellar hydrodynamic equilibrium.
Simple treatment of gravitational radiation. Binary orbit decay by gravity wave emission. Detections of gravitational waves.
Expanding universe dynamics. FRW metric. Accelerating universe, cosmological constant as vacuum energy.

B6 Condensed Matter Physics

Structure and types of condensed matter. Chemical Bonding.
Crystal structure: lattices, unit cells and basis, reciprocal lattices, Brillouin zones.
X-ray and neutron diffraction: Bragg and Laue equations, structure factor, atomic form factor and nuclear scattering length.
Vibrations in lattices: monatomic and diatomic chains, phonons, heat capacity, Einstein and Debye models.
Free-electron theory of metals: Fermi energy and Fermi surface, density of states in 1, 2, and 3 dimensions, heat capacity, electrical conductivity.
Band structure: nearly free electron model for electron dispersion in a periodic potential, tight binding model, band gaps, distinction between metals, semiconductors and insulators.
Direct and indirect gap semiconductors, optical absorption, donor and acceptor impurity doping. Mobility and Hall effect, temperature dependence of carrier concentration.
Magnetic properties of matter: diamagnetism, paramagnetism and Hund's rules, Pauli paramagnetism, exchange interactions, ferromagnetism and Curie-Weiss law, domains.

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.

S04. Energy Studies

Historical development of power generation, global issues. Conservation laws. Application of thermodynamic reasoning to power generation.
Physical principles of thermal power plant. Generation from mechanical sources (hydro, tidal, wave, wind), Solar energy (PV and solar thermal), Biomass, Nuclear fission reactors. Fusion power. Energy storage. Risk assessment. Environmental and economic issues. Future trends.

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, rigid bodies, small oscillations, Noether's theorem and conservation laws, particle in an electromagnetic field. Hamiltonian mechanics: Legendre transform; Hamilton's equations; principle of least action again; Liouville's theorem and flows in phase space; Poisson brackets; symmetries and conservation laws.

[Non-examinable: Canonical transformations; Hamilton--Jacobi equation; action-angle coordinates; ray tracing theory and Hamilton's equations for a wave group; derivation of Schrödinger's equation.]

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

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.

S18: Advanced Quantum Mechanics

Introduction to scattering theory. Classical and quantum scattering. Differential cross-section and the scattering amplitude. One dimensional scattering. The S-matrix. Green's functions methods. The Lippmann-Schwinger equation. Perturbation theory and the Born series. Scattering by a central potential. Method of partial waves, the phase shift. Unitarity and the optical theorem. Relativistic wave equations: the Klein-Gordon equation, the Dirac equation, their properties and solutions.

S26. Stars and Galaxies

Measurement of physical properties of stars and galaxies. Parallax and the distance ladder. Magnitude systems and their relationship to quantitative measurements of luminosity and effective temperature. Observational properties of stars and galaxies: the H-R diagram, stellar clusters, basic description of the structure of the Milky Way; the Hubble classification of galaxies; galaxy luminosity functions.

The equations of stellar structure: hydrostatic equilibrium, virial theorem, convection and energy transport. Structure of main sequence stars; use of scaling relations to derive relationships between stellar masses, luminosities, radii and lifetimes. The Chandrasekar limit and degenerate stellar cores; introduction to post-main sequence evolution.

Galaxies treated as systems of stars in spherically symmetric gravitational potentials. The Collisionless Boltzmann Equation; Jeans' equations; moments of distributions. Stellar velocity dispersions and their use to infer the potential. Influence of a point mass at the centre of the potential; observational evidence for supermassive black holes in normal galaxies.

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.

S32. Chaos, Random Processes and Predictability

The geometry of dynamical systems; fixed points and stability; properties of the Jacobian; limit cycles; control parameters and bifurcations; phase portraits; conservative versus dissipative systems; three-dimensional systems and the Poincare-Bendixon theorem (qualitative account only); the Lorenz system; phase-space volume contraction; strange attractors and fractals; introduction to random processes; distinguishing between low-dimensional chaos and linear stochastic processes; predictability and error growth; Liapunov exponents.

S33. Entrepreneurship for Physicists

The course comprises 12 hours direct teaching with a significant coursework element as the basis of assessment. It has been designed by experts in the Saïd Business School and Oxford Foundry specifically for Physics undergraduates.

Inspiration

Students will receive a series of short talks from ex-Physicists turned entrepreneurs (emphasis on founders of Hard Tech Start-ups), current academics who have their own spin-outs, and academics who license technologies to companies. Examples of start-ups could include those supported through the OXFO L.E.V8 accelerator programme that have been founded by ex-Oxford Physics students such as See-Through Scientific and Veratrak. Showcasing a combination of current academics who have spin-outs and Oxford Physics alumni that have created start-ups will show students that they do not need to leave academia to be enterprising.

Team Building

A leadership coach will help students form diverse high-performing teams of 2-4 people using Belbin team formation methodology. The exercises will help students gain a greater self-understanding of their

strengths and how to manage their weaknesses, enabling them to better contribute to a team. Students will form teams made up of a diverse mix of Belbin team roles.

Creative Thinking & Problem Discovery

Students will be provided with an introduction to design thinking to help them understand what creative problem solving is and how it can be used for innovation. A common pitfall that scientists face when developing products is starting with a solution and looking for a problem.

Design thinking is a powerful methodology to helping students engage with actual customer needs and work towards building insightful and efficient solutions where there is a market opportunity. Students would be shown case studies of Hard Tech companies related to Physics and be tasked with applying the concepts of design thinking to generate an idea for a product or service and begin the process of developing the idea for the people they are designing for.

Intellectual Property (IP) & Licensing

Students will be introduced to the principles of IP and why IP is so critical to new businesses.

The session will cover IP as a value driver for start-ups, how to monetize IP and various methods to protect your IP. Speakers will have a background in managing IP and technology transfer and draw upon their experiences of working with companies. Students will have the opportunity to get first-hand accounts on how business strategy is formed around IP, what opportunities and challenges companies have to face and how to maximise the value of IP.

Market Segmentation & Knowing Your Customer

Students in their newly formed teams will explore how to choose the market segment for their chosen product or service and the methods of "seeing the problem through the customers' eyes." Students will learn and apply the concepts of market segmentation, explore the foundations of primary market research, and develop a customer persona.

Quantifying the Value Proposition & Designing a Business Model

Students will learn how to estimate the quantified value proposition for their team's product or service and gain an understanding of existing business models of companies across industries where disruptive technologies have had a significant impact (e.g. Biotech and Quantum computing) to help students capture some of the value their product or service brings to the customer. Students will be guided through how to use the Business Model Canvas to map and design a business model for their product or service.

The assessment for this course will be as follows:

25% Group presentation: Assessed based on an oral presentation of a business idea/plan.

25% Group written assessment: Student groups will be asked to submit an executive summary of no more than 1000 words, and a slide presentation of no more than 10 slides.

50% Individual Feasibility Study: Individual students will be asked to write a portion (1000 words max) of a document assessing the feasibility of a potential business venture, from one of the following perspectives: the potential market (demand-side), the potential competition (supply-side), and the skill-base of the team.

S34. From Signal to Data

Common sensors and their outputs, equivalent circuits, datasheets, multistage amplifiers, common amplifier building blocks, negative feedback amplifiers, field effect transistors, analogue filters (2^{nd} order filters, active filters) in the time and frequency domain, phase locked loop, noise (types of noise, what to do about noise), lock-in amplifier

Transistor as switch, CMOS, flip-flops, comparators (Schmitt trigger), coincidences, analogue-to-digital conversion (including time-to-digital conversion), digitization error, sampling, aliasing, digital Fourier transform and its use in signal processing, windowing, digital filters (FIR and IIR filters), reconstruction of digital signals, up-/down-sampling, digital-to-analogue conversion

Appendix D Mark scheme for practicals

Students must achieve at least 2 marks to obtain the credit for the practical or report. Once a student has a mark of 2 or higher, they cannot be remarked for the same practical.

Criteria for practical marking

Mark	Criterion
0	• Did not attend the practical • Was absent for more than one hour during the practical: not applicable for online practicals or ones where students spend only part of day in lab
1	• Did not complete the practical (*) • Severe problems with some or all aspects of the practical • Lacked understanding of the physics of the experiment, the method and the apparatus • Limited results • No awareness of uncertainties or analysis marred by serious errors • Notes, graphs and tables absent or totally unacceptable • Commenting in any computer code is absent or inadequate • The student is unwilling or unable to improve the standard to a higher level even after substantial input from demonstrators.
2	• Basic results • Minimally acceptable work with only limited awareness of uncertainties • Plots present but lacking key aspects (e.g. axis labels, data points, clarity) • Very basic data analysis
3	• Reasonable and competent attempt at all aspects of the practical • Reasonable understanding of the physics of the experiment, the method and the apparatus • Notes, graphs and tables will be adequate, but could be improved • Some units or quantities may be wrong • There may be some inappropriate appreciation of numerical precision • Basic commenting of computer code.
4	• Good attempt at all aspects of the practical • Good understanding of the physics of the experiment, the method and the apparatus • Notes, graphs and tables are clear and correctly labelled in a well organised logbook • Good analysis and awareness of a range of types of uncertainty • Only minor errors in any calculations, units or quantities • The appropriate numerical precision required will be shown.
5	• Excellent work, showing scientific maturity and evidence of analysis, ideas or techniques well beyond those expected for the practical, for example a full awareness of statistical and systematic errors • Exhibits insight and possibly originality, combined with a very good ability to analyse and synthesise the results • Computer code will be thoroughly and clearly commented • Demonstrates a full understanding of the physics in the practical • Cannot be awarded for work submitted late.

*: Students who do not complete a practical can obtain a mark higher than 1 if the demonstrator feels the student fully understood all parts of the experiment which were completed and/or progress was hindered due to faulty equipment.

Criteria for report marking

Mark	Criterion
0	• Did not a write a report
1	• Severe problems with some or all of the structure of the report and plots • Limited results • No awareness of uncertainties • Referencing is absent or totally unacceptable • Inadequate English.
2	• Basic results • Minimally acceptable work with limited awareness of uncertainties • Plots present but lacking key aspects (e.g. axis labels, data points, clarity) • Very basic data analysis and discussion of results • Minimal referencing (e.g. to experimental script only).
3	• Reasonable attempt at all aspects of the report • Adequate plots, data and uncertainty analysis • Evidence of reading beyond the script e.g. in a textbook • Awareness of numerical precision • Basic commenting of any included computer code.
4	• Well organised report of good quality • Clear plots, labelled diagrams and good analysis • Awareness of a range of types of uncertainty • All references included appropriately, beyond just the lab script.
5	• Excellent work • Shows scientific maturity and evidence of analysis, ideas or techniques well beyond those expected, for example a full awareness of statistical and systematic errors or using ideas from research papers • Any included computer code will be thoroughly and clearly commented. • Demonstrates a full understanding of the physics in the practical or contained in the computer code (if applicable) • Cannot be awarded for work submitted late.

Appendix E Summary of Part B experiments

This section lists the experiments available. A completed experiment earns two day's credit unless otherwise indicated. Scripts can be obtained from SPIRe or in the relevant section of Canvas.

Optics

Location: Rooms 209 and 215 Head of Lab for Part B: Prof. Alexander Lvovsky

For the academic year 2021-21, all of these experiments must be prebooked before arriving in the teaching laboratories. You MUST arrive at the start time for the lab and all covid procedures must be followed whilst you are in the teaching laboratories. If you do not follow these procedures you will be asked to leave the teaching laboratories.

Mini-projects are indicated with (mp) after the practical title. Mini-project bookings are for two consecutive weeks; in the first week you do, and are marked for, the basic experiment. In the second week you do the more open ended mini-project part.

OP32 Isotope shift and fine structure in hydrogen

A photographic study of detailed structure in the Balmer lines using a Fabry-Perot etalon. Basic atomic physics is investigated by high resolution spectroscopy.

OP33 Hyperfine structure of cadmium (mp)

A study of hyperfine structure using a Fabry-Perot etalon. The results can be used to determine the nuclear spin of ^{111}Cd and ^{113}Cd. In the first instance, measurements are made both by photographing the interference fringes and by pressure scanning of the fringes with photo-electric recording.

OP34 The Zeeman effect (mp)

The Zeeman effect (both normal and anomalous) is studied in the spectral lines of cadmium using a Fabry-Perot etalon. We examine the polarization of the split spectral lines perpendicularly to the magnetic field and parallel to it. Basic atomic physics is combined with high resolution spectroscopy techniques. The mini-project component is a study of the splitting in the mercury spectrum.

OP35 The helium-neon laser (mp)

In this experiment a helium-neon (He-Ne) laser is built from a discharge tube and a variety of cavity mirrors, and the properties of the laser investigated. The requirements on the cavity mirrors to achieve a low-loss mode are established theoretically and confirmed by experiments. Measurements of the transverse profile of the lowest-order cavity mode are compared with theoretical expectations, and operation on a higher-order mode is demonstrated. Lasing on transitions in addition to the familiar transition at 632.8 nm is demonstrated by introducing dispersive elements into the laser cavity.

OP36 Image formation in the microscope

A coherently illuminated object is imaged by a lens. In the focal plane of the lens there appears the Fourier transform of the object. By blocking out certain parts of this plane (i.e. by filtering out certain Fourier components) one can change the image dramatically. Simple spatial filters can remove a raster to

demonstrate the Abbe theory of microscope resolution, and to demonstrate phase contrast, dark-ground microscopy and Schlieren.

OP37 Preparation and measurement of photon polarization states

Polarization state of light as a quantum object. Hilbert space of polarization states. Polarization transformations by waveplates as operators. Polarization state measurement in a given basis. Arbitrary state preparation. Reconstructing the state by measuring it in multiple bases (quantum state tomography). Note you cannot do this practical if you did OP27 in the second year.

OP38 Quantum entanglement

Generating photon pairs by parametric down-conversion. Heralded preparation of single-photon states. Polarization entanglement. Remote preparation of polarization states of one of the photons in a pair by measuring the polarization of the other photon. Quantum nonlocality and testing Bell's inequality.

Condensed matter physics

Location: Room 127 Head of Lab: Prof. Robin Nicholas/Dr. Moon-Sun Nam

For the academic year 2021-21, all of these experiments must be prebooked before arriving in the teaching laboratories. You MUST arrive at the start time for the lab and all covid procedures must be followed whilst you are in the teaching laboratories. If you do not follow these procedures you will be asked to leave the teaching laboratories.

Mini-projects are indicated with (mp) after the practical title. Mini-project bookings are for two consecutive weeks; in the first week you do, and are marked for, the basic experiment. In the second week you do the more open ended mini-project part.

SS03 Hall effect in semiconductors

The Hall coefficient and resistivity of both p-type and n-type InSb are measured between 77 K and 300 K. This experiment clearly illustrates many concepts covered in the third year lectures, including mobility, minority carriers, effective mass and the two carrier Hall effect; in the past it has been used as the basis of a number of finals questions! Experiment now 2 days.

SS05 The magnetophonon effect

Introduces phonons, the quantised vibrations of the ions in a solid (sound waves are low energy phonons), the quantum-mechanical equivalent of cyclotron motion of electrons in a magnetic field, and the use of computers to record data. Measurements carried out at 77 K plus a little numerical processing allow the effective mass of electrons in InSb to be deduced.

SS07 The quantum Hall effect (mp)

This experiment demonstrates that the Hall resistance of two-dimensional electrons is quantised very exactly. Hall effect data acquired using a high-field superconducting magnet and a computer data-acquisition system are used to determine the fine-structure constant to an accuracy of one part in 1×10^5.

SS08 Superconductivity

Superconductors have an immeasurably small (or zero) electrical resistance. This experiment demonstrates this property, plus phenomena such as persistent currents and the Meissner effect. It also provides an introduction to data acquisition and processing using computers.

SS09 Superconducting quantum interference device

This experiment explores a Superconducting Quantum Interference Device (SQUID) as a means of performing sensitive measurements of magnetic fields, and of converting frequency into voltage through the 'Shapiro Step' effect.

SS12 Paramagnetic resonance (mp)

Magnetic resonance is used widely in medicine, biology, geology etc. The experiment explores electron spin resonance at 10 GHz. Aspects of second year statistical mechanics and quantum mechanics lectures are covered and topics from third year solid state lectures can be studied.

SS14 Nuclear magnetic resonance (1 day)

Nuclear magnetic resonance (NMR) is used widely in medicine and biology. In this experiment, a simple NMR spectrometer running at 10 MHz – 20 MHz is used to study H and F nuclei and to illustrate the basic principles of the technique.

SS16 X-ray diffraction (mp)

The study of the lattice structures of crystals using X-ray diffraction techniques. A range of experiments are undertaken using new X-ray sets, which allow computer controlled acquisition of X-ray spectra and powder diffraction using photographic film.

SS20 Adiabatic demagnetization

The attainment and measurement of temperatures down to \SI{0.3}{\kelvin} using liquid helium and the adiabatic demagnetisation of a paramagnetic salt.

SS24: Earth's field NMR/MRI

This experiment aims to introduce the concepts necessary to perform and interpret a basic nuclear magnetic resonance (NMR) experiment. Additionally a basic one-dimensional magnetic resonance image (MRI) will be constructed.

Nuclear physics

Location: Room 230 (Partially online in 2021-2022, mainly in person) Head of Lab: Prof. Giles Barr
For the academic year 2021-21, all of these experiments must be prebooked before arriving in the teaching laboratories. You MUST arrive at the start time for the lab and all covid procedures must be followed whilst you are in the teaching laboratories. If you do not follow these procedures you will be asked to leave the teaching laboratories.

Due to the use of radioactive sources in this laboratory, a senior demonstrator must be present at all times. For this reason, the lab usually shuts at lunchtime.

Mini-projects are indicated with (mp) after the practical title. Mini-project bookings are for two consecutive weeks; in the first week you do, and are marked for, the basic experiment. In the second week you do the more open ended mini-project part.

NP01 Energy loss by ionisation
The path of a charged particle moving through matter is marked by a trail of liberated electrons; their energy drawn from the kinetic energy of the particle. Detection of these electrons underlies almost all forms of particle detector. This experiment is all about measuring the energy loss of alpha particles in gases.

NP03 γ-ray spectroscopy (mp)
A GeLi spectrometer is calibrated with sources of known energy and then used to investigate the γ-ray spectra associated with the β-decay of ^{108}Ag (simple) and ^{110}Ag (complicated).

NP04 life-time of a gamma emitting state
241Am decays by alpha-emission to a 60 keV state in 237Np by which decays by emission of a 60 keV gamma-ray. The lifetime of this state is measured using alpha-gamma delayed coincidence techniques.

NP08 Muon lifetime measurements (mp)
Muons are heavy electrons which decay into an electron (and two neutrinos) with a mean lifetime of 2 μs. Muons produced as a result of cosmic radiation interactions in the upper atmosphere filter down to DWB level 2 and some stop in a cylinder of plastic scintillator. Set up an electronic trigger for stopping muons and measure the distribution of time intervals between muons stopping and the decay electron.

NP10 search for mesons containing b-quarks (mp) (Online only)
In this experiment, you will use software tools to analyse real data from the CDF high energy physics detector at the Fermilab Tevatron to search for elementary particles. You will be using muons, which are relatively long-lived to try to reconstruct what happened at the interaction vertex. It should be possible to reconstruct the existence of mesons containing charm and beauty quarks which were created in the interaction and decay very nearby and measure their properties. The software tools require you to write some bits of code (guided by examples) in C++. It helps in this practical to either know some C++ or have used the ROOT framework in the past, however the examples given should

point the way and the practical ought to be accessible to anyone with some coding experience in any computer language.

NP11 LHC silicon detector (available in TT2022 only)

In this practical you will investigate the structure and the principles lying behind the operation of a silicon microstrip detector - similar to those used in CERN for particle detection. You will learn about calibration of such devices, storing and reading data, trigger systems, and algorithms used to analyse the results. This will involve writing simple scripts in MATLAB. You must read the theory section before coming to the lab.

Physics of atmospheres and oceans

Location: Room 221 (Computing lab) **Head of Lab: Dr. Anu Dudhia**

For the academic year 2021-21, all of these experiments must be prebooked before arriving in the teaching laboratories. You MUST arrive at the start time for the lab and all covid procedures must be followed whilst you are in the teaching laboratories. If you do not follow these procedures you will be asked to leave the teaching laboratories.

Mini-projects are indicated with (mp) after the practical title. Mini-project bookings are for two consecutive weeks; in the first week you do, and are marked for, the basic experiment. In the second week you do the more open ended mini-project part.

AP01 Remote sounding (mp)

The operation of an infrared radiometer is investigated. The instrument is radiometrically calibrated and the sensitivity and field of view determined. Once calibrated, the instrument is used remotely to measure the temperature of different targets.

AP03 Remote sensing from satellites (mp)

An infrared image of the Earth recorded by the geostationary Meteosat satellite is analysed using a computer. Standard techniques of image registration and radiometric calibration are investigated to determine sea-surface, land, and cloud top temperatures.

AP05 Fun with a wavetank

In this experiment a wave tank is used to investigate the properties of shallow-water waves. The dispersion relation is investigated for different depths of water and wave amplitudes, and the effects of wave `breaking' are demonstrated.

Astrophysics

Location: Room 221 (Online for weeks 1-4 in MT, in person afterwards)

Head of Lab: Prof. Dimitra Rigoloulou

The Astrophysics experiments are computer based, carried out singly and are marked via a sign up on Canvas the week after you carry out the experiment.

For the academic year 2021-21, all of these experiments must be prebooked before arriving in the teaching laboratories. You MUST arrive at the start time for the lab and all covid procedures must be followed whilst you are in the teaching laboratories. If you do not follow these procedures you will be asked to leave the teaching laboratories.

Astrophysics experiments MUST be pre-booked on SPIRe - if you do not book and then turn up to be marked you may be turned away.

Doing Astrophysics practicals on one's own laptop is strongly discouraged because of the IT support issues. If your laptop even slightly differs from the settings on the computer room Macs it can be complicated to set up the required software, and the Physics Department will not be able to support this.

Mini-projects are indicated with (mp) after the practical title. Mini-project bookings are for two consecutive weeks; in the first week you do, and are marked for, the basic experiment. In the second week you do the more open ended mini-project part.

AS33 The mystery transiting exoplanet

The goal of this experiment is to measure the mass, radius and temperature of a 'mystery' transiting exoplanet, in order to identify it and to infer a crude estimate of its bulk composition.

AS35 Colour-magnitude diagrams of open clusters (mp)

In this experiment, you will use observations taken with the Philip Wetton Telescope to study the colour-magnitude diagram of an open stellar cluster. The practical uses a range of software tools and introduces techniques to calibrate the raw data, reduce the science images and carry out aperture photometry. Isochrones are then used to fit the photometric data and deduce the physical properties of the cluster.

AS37 The Hubble diagram for type Ia supernovae

Constraints on the values of cosmological parameters are determined by statistical analysis of a sample of type Ia supernovae. Results present one of the key pieces of evidence in favour of a non-zero Cosmological Constant. Best-fitting values of the energy density in matter and in dark energy are derived together with their statistical uncertainties.

AS38 Gas and Star Formation in Spiral Galaxies

Molecular insterstellar gas is the prime ingredient used by galaxies to form their stars. While the specific process of converting gas into stars depends on many parameters, the rate at which a galaxy forms stars should be directly proportional to its molecular gas mass. In this practical you will use spectral image

maps from the Atacama Large Millimetre Array (ALMA) in Chile to measure the molecular gas content of a spiral galaxy. The stellar content of the same galaxy will be determined through analysis of near-ultraviolet and mid-infrared data taken from Space Telescopes. These measurements will enable you to investigate the complex process by which galaxies form their stars out of their molecular gas reservoir and determine the uncertainties involved in such measurements.

Biophysics

Rooms 214 and 216, DWB **Head of Lab: Prof. Sonia Contera**

For the academic year 2021-21, all of these experiments must be prebooked before arriving in the teaching laboratories. You MUST arrive at the start time for the lab and all covid procedures must be followed whilst you are in the teaching laboratories. If you do not follow these procedures you will be asked to leave the teaching laboratories.

Mini-projects are indicated with (mp) after the practical title. Mini-project bookings are for two consecutive weeks; in the first week you do, and are marked for, the basic experiment. In the second week you do the more open ended mini-project part.

Experiments are designed to introduce students to some of the techniques of modern biophysics, and to some biological systems that can be studied with these techniques.

BP01 Light microscopy (mp)

Image formation in a microscope is essentially an interference phenomenon. Spatial filtering of images will be explored and the Abbe theory of microscope resolution tested. Fluorescence microscopy and phase-contrast methods including differential interference contrast (DIC) will be used to observe and record images of plant and animal cells with a CCD camera. Various physical and biological microscopic phenomena will be observed and measured using different forms of microscopy.

BP02 Optical tweezers

A single-beam optical trap or optical tweezers allows micron-sized transparent particles to be held in a focused laser beam by forces on the order of a few piconewtons. The position of the particle can be measured with nanometre accuracy by measuring the displacement of the beam. A simple optical trap with position detection will be demonstrated and the force and displacement calibrated by measurement of the Brownian motion of the particle. The trap will then be used to observe the rotation of a living, molecular, rotary electric motor; the bacterial flagella motor.

BP03 Atomic force microscopy (AFM) (Only offered in even weeks)

The atomic force microscope is a new technique that allows individual atoms to be resolved on flat surfaces. It is also becoming a powerful tool for the examination and manipulation of single biological molecules. The basic principles and operating modes of the AFM will be explored and simple specimens such as vinyl records and compact discs will be imaged. If possible, the practical will also include the

imaging of single DNA molecules on mica surfaces and investigations of the properties of different kinds of DNA molecule.

BP04 Single-molecule fluorescence (only available in odd weeks) – runs in the Clarendon lab not the Teaching Labs – see below for details

Single-molecule fluorescence spectroscopy is an ultrasensitive method that can interrogate individual molecules of biological and non-biological matter for properties such as their three-dimensional location, structure, interactions and dynamics. The practical will use a popular format of wide-field imaging of surface-proximal fluorophores to study DNA and protein samples labeled with fluorescent dyes.

Specifically, total-internal-reflection of laser light at a water-glass interface will be used to generate evanescent-wave excitation within a thin layer just above a surface; surface-immobilized fluorescent molecules will then be imaged on a CCD camera. Using this geometry, hundreds of molecules can be observed in parallel for up to minutes. The practical will involve an initial calibration of the instrument using fluorescent beads as well as measurements of nanometer scale distances within DNA standards (based on resonance energy transfer between fluorescent probes). Examples of single-molecule dynamics will also be examined based on real-time fluorescence signal fluctuations due to structural changes in protein and DNA samples.

This practical now runs in the Clarendon laboratory, room 202 (not the teaching lab area/DWB). The demonstrator will meet the students in the reception of the Clarendon lab/Beecroft building at 10:00 on the first morning of the practical, and then will meet them in the Clarendon, in front of 202, where BP04 will be located, (top of the main staircase, 2nd floor), before each session.

Appendix F 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. 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).