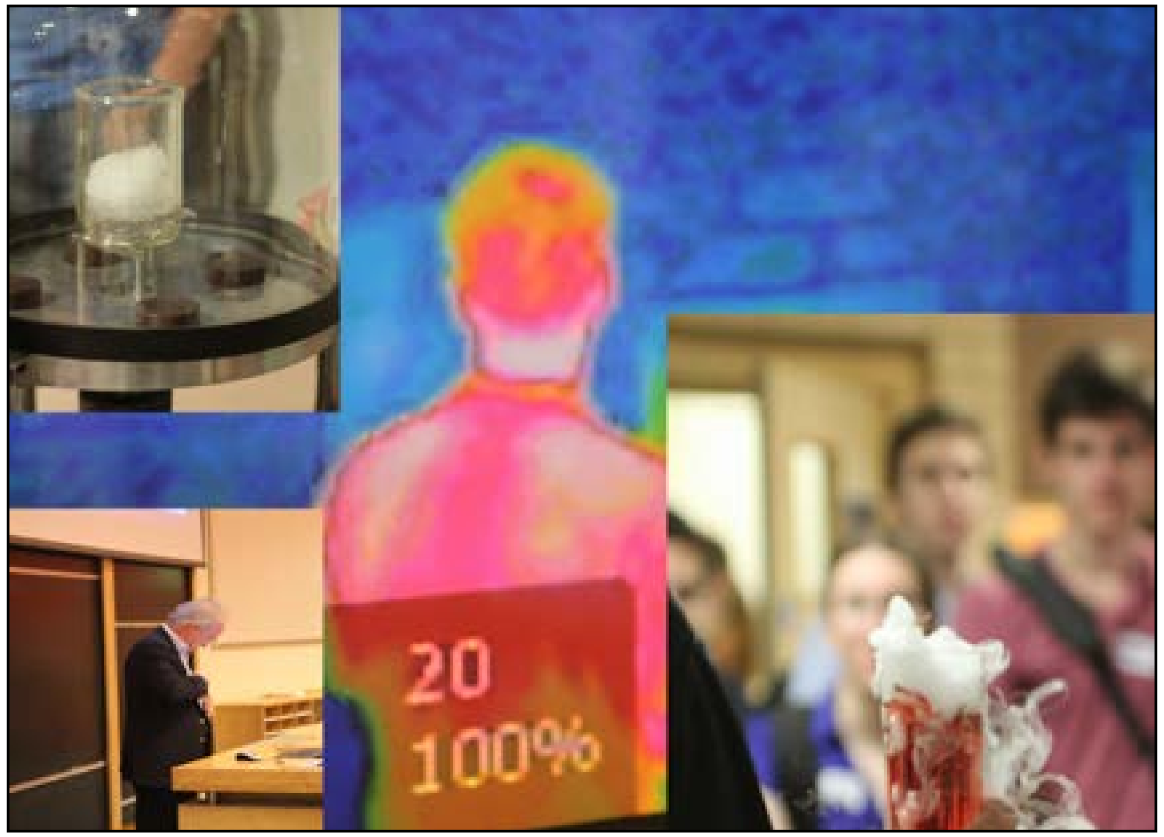
Photo: Alan Segar

2015 - 2016

Physics

Undergraduate Course Handbook

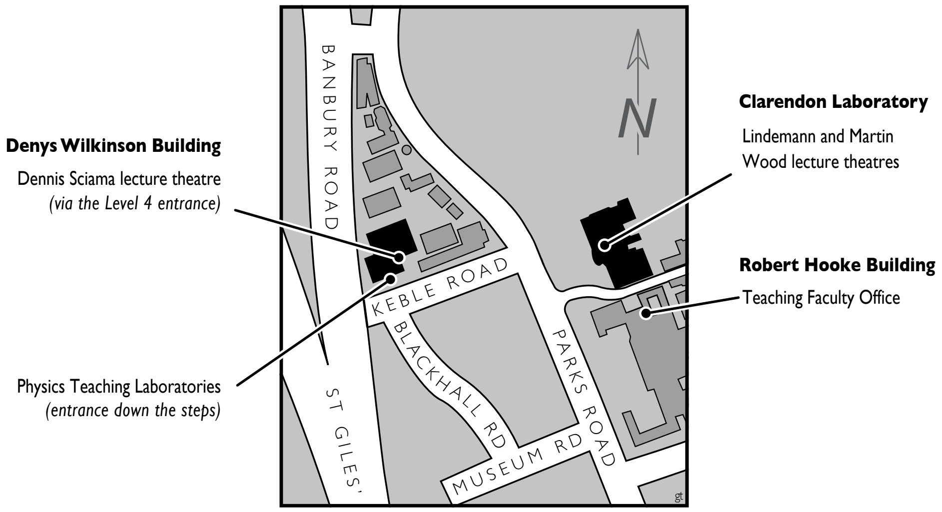
2015-2016



Open Day Images

The Course

These notes have been produced by the **Department of Physics, University of Oxford**. The information in this handbook is for the academic year Michaelmas Term 2015, Hilary Term 2016 and Trinity Term 2016.



The Department is able to make provision for students with special needs. If you think you may need any special requirements, it would be very helpful to us if you could contact the Assistant Head of Teaching (Academic) about these as soon as possible.

Students in wheelchairs or with mobility needs can access the Lindemann and the Dennis Sciama Lecture Theatres by lifts from the ground floors. The Denys Wilkinson Building and the Clarendon Laboratory have toilet facilities for wheelchair users. The Martin Wood Lecture Theatre has access for wheelchairs and a reserved area within the theatre. There are induction loop systems for students with hearing difficulties in the Lindemann, Dennis Sciama and Martin Wood Lecture Theatres. Other provisions for students with special needs can be also be made.

The Physics Teaching Faculty Offices can be found in the Robert Hooke Building on the Ground Floor.

Contents

Contents Continued

How to use this handbook

This handbook applies to students starting the course in Michaelmas term 2015. The information in this handbook may be different for students starting in other years.

Students in their first year should read the two sections 'Introduction' and 'First Year' (see page 13) in detail and skim the remainder for an overview of the courses. Students in later years should read the sections on the FHS (Final Honours School) examination structure, the details for the relevant year and be aware of the overall requirements and content of their chosen course.

Syllabuses
Appendix C - Prelims
Appendix D - Part A
Appendix E - Part B
Appendix G - Short Options
Appendix H - Part C

At the end of this handbook are appendices giving the syllabuses for the examination papers to be taken in Trinity Term 2016 for Physics Prelims, FHS Parts A and B for the three year BA and four year MPhys courses, and for the Physics papers for the Physics and Philosophy course. Syllabuses are also given for the Part C 4th year Major Option papers.

The handbook gives a comprehensive book list for the whole course, important dates for the academic year, information about the undergraduate consultative committee (PJCC) and a list of people involved in organising the course.

Practical Course
Practical Course Handbook

Full details about the Practical Course are given in the *Practical Course Handbook* at http://www-teaching.physics.ox.ac.uk/practical_course/OnLineScripts.html.

Members of staff will be happy to answer any questions you might have that are not answered in our printed and online documentation, but for particular information about College teaching, students should contact their tutors. Further information about the courses can be obtained from the Department of Physics website http://www2.physics.ox.ac.uk/students/undergraduates and from the Physics Teaching Faculty.

In this document, Michaelmas Term, Hilary Term, Trinity Term refer to Michaelmas (Winter), Hilary (Spring) and Trinity (Summer) 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 term.

Prof Jonathan Jones, Head of the Physics Teaching Faculty

General Information
http://www2.physics.ox.ac.uk/students/undergraduates

For full and up-to date information on lecture timetables, see the Physics Department's *Lecture Database* (www.physics.ox.ac.uk/lectures).

Lecture timetables
www.physics.ox.ac.uk/lectures/

The examination times given in this handbook are based on information available in September 2015. These may be altered and the definitive times are those published by the examiners; these will be posted on the official examiners' web page. The lecture times in Hilary and Trinity Term 2016 are also subject to possible change and the actual times will be given in the Lecture Database which is published on the physics website just before the beginning of each term.

Examination Matters
www.physics.ox.ac.uk/teach/exammatters.htm

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

The information in this handbook is accurate as at 5 October 2015, however it may be necessary for changes to be made in certain circumstances, as explained at http://www.ox.ac.uk/admissions/undergraduate/courses-listing/physics. 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.

Introduction

The Physics Department

The Oxford University Physics Department is one of the largest in the UK, with an average annual intake of about 180 undergraduates, of whom 120 study for a MPhys, 45 for a BA in Physics and 15 for an MPhysPhil in Physics and Philosophy. There are about 104 academic staff based in six sub-Departments: Astrophysics; Atmospheric, Oceanic and Planetary Physics; Atomic and Laser Physics; Condensed Matter Physics (including BioPhysics); Particle Physics and Theoretical Physics. These represent the main areas of research carried out in the Department.

Textbooks

Appendix A

The Department is located in five buildings as shown on the map inside the front cover: the Denys Wilkinson Building (DWB) and the Theoretical Physics building on the west side of Parks Road, and the Clarendon Laboratory, the Atmospheric Physics building and the Robert Hooke building on the east side. **You will need to use your University card to gain access to all physics buildings.**

The Physics Teaching Faculty

All undergraduate teaching is arranged and organised in the Department by the Physics Teaching Faculty. The Physics Teaching Faculty Office is located in the Robert Hooke Building (Department of Physics)

Oxford University Computer Usage Rules and Etiquette

http://www.it.ox.ac.uk/rules

Practical Laboratories

All the undergraduate teaching laboratories (Atmospheric Physics, Astrophysics, General Physics, Thermal Physics, Electronics, Electrostatics and Magnetism, Optics, Condensed Matter Physics, Computing, Nuclear Physics and Biophysics) are located on the lower two floors of the DWB, together with a reception area where undergraduates can meet and obtain refreshments; the entrance is from Keble Road down a flight of steps.

Lecture Theatres

There are lecture rooms in all buildings, the main ones being the Martin Wood and Lindemann Lecture Theatres in the Clarendon and the Dennis Sciama Lecture Theatre in the DWB. To enter the DWB, go up the wide concrete steps from Keble Road; turn left at the top and the entrance is facing you. Once inside, the lecture theatre is one floor up from the entrance. The current entrance to the Clarendon is from the Martin Wood Building where you will find the Martin Wood Lecture Theatre. The Lindemann Lecture Theatre is on the first floor.

Libraries

College libraries are generally well stocked with the recommended physics textbooks, but if your library is without a book you need you should tell your tutor or your College librarian. A list of the books recommended by the lecturers is given in **Appendix A**. The Radcliffe Science Library (RSL) in Parks Road also has a comprehensive collection of physics books and journals and you may use this library, provided you have your University card with you.

Computers

There are numerous computer workstations in the teaching laboratories on Level 2 of the DWB. Students can use the computers at any time during office hours and during vacations. The Colleges all have computing facilities for their undergraduates and there is a University-wide network, which enables students to access Departmental sites, the practical course and the internet. Undergraduates will also receive an account and a College e-mail address on the University computing system. All new users will be asked to sign an undertaking to abide by the University Rules on the use of computers (see http://www.ict.ox.ac.uk/oxford/rules). Students should check their e-mails regularly, **at least once a day during term**.

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

Social spaces and facilities

Students are allowed to use the Common Rooms in the Clarendon Laboratory and the DWB for meals and refreshments. There are vending machines in the reception area of the teaching laboratories in the DWB and in the corridor on the first floor of the Clarendon Laboratory between the Lindemann and the Martin Wood Lecture Theatres. **You may not take any food or drink into the lecture theatres, the teaching laboratories or near any computers.**

Data Protection

Data Protection Act

www.admin.ox.ac.uk/councilsec/dp/

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

University Policy in Intellectual Property

Appendix K

The University of Oxford has in place arrangements 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 provided in **Appendix J**.

Licensed Copying User Guidelines

Copyright Legislation

https://www1.admin.ox.ac.uk/asuc/licences/

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. More details are provided at https://www1.admin.ox.ac.uk/asuc/licences/copy/and in **Appendix K.**

Good academic practice and avoiding plagiarism

Citations and Plagiarism

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

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

The Teaching Faculty uses "*Turnitin* as a tool that allows papers (projects) to be submitted electronically to find whether parts of a document match material which has been previously submitted .... This is very useful in training students in good citation practice..." [Ref: Oxford University IT Service]

All work submitted will be checked with Tunititin.

Support for Students with Special Needs

Disability website

www.admin.ox.ac.uk/eop/disab/

The Department is able to make provision for students with special needs. It would be useful to us if you could contact the Assistant Head of Teaching (Academic), see **Appendix N**, who is the Disability Contact for the Department, about your requirements.

See http://www.admin.ox.ac.uk/eop/disab/ for more information. The *Examination Regulations* provides guidance for students with special examination needs. See the *Examination Regulations* http://www.admin.ox.ac.uk/examregs/ for more information.

Communications

Communications

E-mail college and other e-mail accounts

Messenger service

Examination Matters

https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters

Academic staff have pigeon holes in the building where they have an office and there is a messenger service that can be used to deliver mail between Colleges and Departments. Staff may also be contacted by telephone or by e-mail. All administrative information about the course and the examinations is sent to students by e-mail. It is **essential** that students using e-mail accounts, other than their college account, **joe.bloggs@college.ox.ac.uk**, set the forwarding appropriately and check their e-mail regularly, **at least once a day during term.** This can be done from College as well as the Department. Some important information from the Physics Teaching Faculty and University is sent to individual students by the messenger service, or is distributed via College Senior Physics Tutors. Notices about the examinations are posted on the official examiners' web page www.physics.ox.ac.uk/teach/exammatters.htm.

Student Life, Support and Guidance

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

PJCC

http://www2.physics.ox.ac.uk/students

Appendix L
Compulsory on-line feedback

Careers Advice

www.careers.ox.ac.uk

Examinations: complaints
www.admin.ox.ac.uk/proctors/info/pam/

Graduate jobs & further study

http://www.ox.ac.uk/students/life/experience

www.aspire.ox.ac.uk

Surveys

http://www.admin.ox.ac.uk/ac-div/resources/surveys/

Institute of Physics

http://www.iop.org/tailored/students/

Details of the wide range of sources of support are available more widely in the University and from the Oxford Students website (www.ox.ac.uk/students/welfare), including information in relation to mental and physical health and disability. Students are encouraged to refer to http://www.ox.ac.uk/current_students/index.html for further information.

Your College tutors provide advice about the Physics courses, and information is also available from the Physics Teaching Faculty in the Robert Hooke Building. You can find academic staff in the Department by asking the receptionists in the DWB or the Clarendon, or the support staff in room 3.1 of Theoretical Physics. Photographs of the staff are displayed outside the Common Room in the Clarendon and in the reception area of the DWB, and in the entrances of the Theoretical and Atmospheric Physics buildings.

Complaints and appeals

In **Appendix M**, you will find precise details for complaints and appeals.

Careers Advice and Graduate Study

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

The Physics Joint Consultative Committee (PJCC)

The **PJCC** has elected undergraduate members who meet twice in MT and HT, and once in TT to discuss both academic and administrative matters with academic staff representatives. 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 and practical feedback forms, a specimen of these can be found in **Appendix L**. See https://pjcc.physics.ox.ac.uk/ for more information. These are a valuable source of information for the Department's Academic Committee, which organises the lectures and is in charge of the Physics courses. The feedback provided is used as part of the continuing review and development for Departmental, University and QAA quality assurance. Students are encouraged to make full use of the on-line management system for feedback on the practicals.

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

Mathematical, Physical and Life Sciences (MPLS) Division

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

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

The Institute of Physics

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

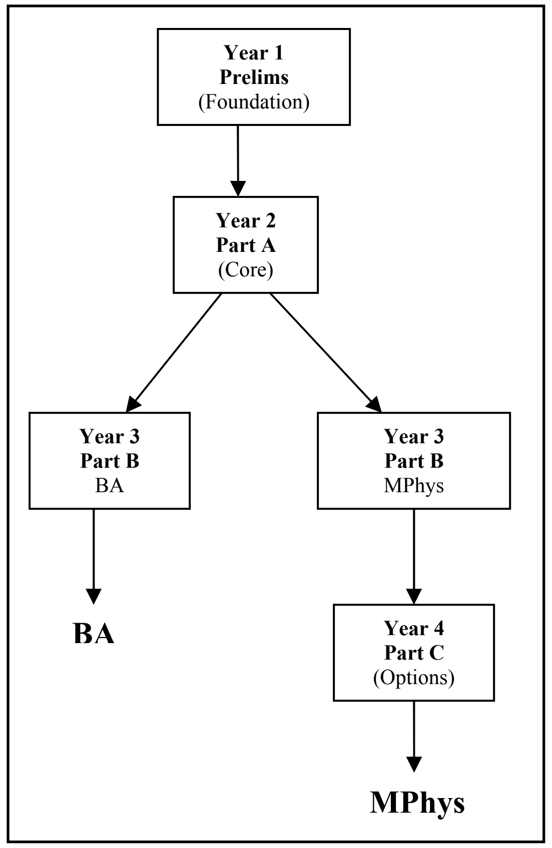
Aims and objectives, teaching and examinations

The Physics Courses – Aims and Objectives

Both the 3-year BA and the 4-year MPhys courses are designed to provide an education of high quality in physics, in a challenging but supportive learning environment, which will encourage all students to develop independent and critical habits of thought and learning. Both courses develop transferable skills related to communication, computing, and problem solving. Their aim is to ensure that, on graduation, all students will be in a position to choose from many different careers, and have the skills, knowledge and understanding to make a rapid contribution to their chosen employment or research area, and that those with the aptitude are prepared for postgraduate study in physics, and thus contribute to the vitality of UK research.

On completion of either course, students should have developed a thorough understanding and broad knowledge of the general theoretical and experimental scientific principles of physics, so that they have the resources to apply their knowledge to a wide range of physical phenomena. They should have learned the techniques required in a modern mathematically-based physics course, gained an understanding of the conceptual structure associated with the major physical theories, understood how to set up simple models of physical problems and learned a wide range of problem-solving skills, both analytical and computational, and how to apply them in contexts that may not be familiar. Students will also have learned the experimental techniques required by working physicists involving sound and safe procedures, how to record and analyse data and how to write accounts of laboratory work which can be clearly understood by other scientists, and will have investigated experimentally some of the most important physical phenomena.

Course Structures



On completion of their course, BA students will have gained some experience of working in a group on an open-ended assignment and all students will have had the opportunity either to acquire some expertise in a more specialised area of physics of their choice, or to broaden their education by study of a foreign language. MPhys students, in addition, will have acquired in-depth knowledge in two chosen specialisations within physics, and – from their project work – they will have learned how to plan and execute an open-ended piece of work, and will have gained experience of a research environment.

Subject Benchmark Statements

"Subject benchmark statements ... represent general expectations about standards for the award of qualifications at a given level in terms of the attributes and capabilities that those possessing qualifications should have demonstrated." [Ref. Quality Assurance Agency, 2008] More details at http://www.qaa.ac.uk/Publications/InformationAndGuidance/Pages/Subject-benchmark-statement-Physics-astronomy-and-astrophysics.aspx

Department and College Teaching

The teaching of the courses is carried out through lectures, practical work in the laboratories, tutorials in the colleges (to which the academic staff are also attached), and classes.

There are comprehensive and challenging lecture courses, in which lecturers are allowed flexibility in their approach, which may lead to the inclusion of material reflecting developments in the field not contained in standard textbooks. Lectures are generally regarded as essential, but they are not in fact compulsory. Printed notes, problem sheets and other handouts frequently support them. Students need to learn how to take good lecture notes, and supplement them with their own private study, using textbooks and other sources recommended by the lecturers and their tutors.

Students are encouraged take their own notes or to amend handouts as they find appropriate. Teaching material, including lecture notes or handouts must not be made available on the web without permission. Publishing material, including your version of the notes, without permission, may be in breach of Copyright. Please note that all lecture notes are only available from the Oxford domain for students.

Physics depends on experimental observations, and learning how to perform and design experiments effectively is an essential part of physics education. Practical work is recorded in logbooks, and some practicals have to be written up. Termly progress reports on laboratory work are sent to College tutors. During the first three years practical work is compulsory; more details are given in the year-by-year sections.

The College-based tutorial teaching provides guidance on what to study, and in what order, coupled with week-by-week work assignments. These assignments are generally problems, with the occasional essay. This is a "Socratic" mode of instruction in which students' understanding is rigorously and individually probed and expanded. College examinations (**Collections**) monitor students' progress during the intervals between University examinations, and students are given regular reports on their progress.

For the more specialised Major Options in Part C of the MPhys course, tutorials are replaced by classes organised by the Department. Attendance at these classes is compulsory, and records are kept of students' progress.

Programme Specifications

Programme Specifications for the Physics courses and the Physics and Philosophy course can be found at http://www2.physics.ox.ac.uk/students/undergraduates

Accreditation

The 3-year BA and the 4-year MPhys courses are accredited by the Institute of Physics.

Vacations

At Oxford, the teaching terms are quite short – they add up to about 24 weeks in one year. Therefore it is essential that you set aside significant amounts of time each vacation for academic work. The course assumes that you will do this in preparation for College collections that are held at the end of 0th week. You should go over the tutorial problems and your notes, revising the material and supplementing it by information gained from tutorials and from your own reading. In addition to consolidating the previous term's work, there may be preparatory reading for the next term's courses. Your tutors may also set you some specific vacation work.

Accessing the Physics Teaching web pages

When you are away from Oxford, you may need to access materials on the web which are restricted. In the first instance, access to restricted resources from outside the Oxford network is provided via the Oxford University Computing Services (OUCS). See http://www.ox.ac.uk/students/life/it/access Virtual Private Network (VPN) Service. A VPN connection provides your computer with a "virtual" connection to the Oxford network - it then behaves exactly as it would if you were actually on-campus. More information can be found at http://www.oucs.ox.ac.uk/network/vpn/.

For access to e.g. lecture notes, use your SSO (Single Sign-On) username (coll1234) with your WebLearn password.

Examinations

The First Year exams (**Prelims**) consist of four compulsory papers, a Short Option paper and satisfactory completion of practical work. The compulsory papers are individually classified as Pass and Fail, with a Pass mark of 40%. The examiners will take into account the performance in the whole examination (the four Compulsory Papers, the Short Option paper and Practical Work) when considering the award of a Distinction and when considering borderline scripts. A failed compulsory paper can be re-taken in September. The University requires that these papers must be passed at no more than two sittings: see the *Examination Regulations* ('The Grey Book') for full details. The current syllabuses for the Prelims are given in **Appendix C** and a copy of the Examination Regulations in **Appendix H**. See **Appendix B** for information about the types of calculators which may be used in the Public 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 (details in Year sections and the formal Regulations are given in **Appendix I**). 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, Parts A and B 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 **Appendices D - G**.

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.

<u>Class I</u>: the candidate shows excellent problem-solving skills and excellent knowledge of the material, and is able to use that knowledge in unfamiliar contexts;
<u>Class II.1</u>: the candidate shows good problem-solving skills and good knowledge of the material;
<u>Class II.2:</u> the candidate shows basic problem-solving skills and adequate knowledge of most of the material;
<u>Class III:</u> the candidate shows some problem-solving skills and adequate knowledge of at least part of the material;
<u>Pass:</u> 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 and 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.

Assessment of Practical Work

A: First Year (Prelims)

Prelims practical work must be complete with an up to date computer record by noon on the Friday of 1st week of Trinity, and students should complete their practical work by the end of Hilary. The *Examination Regulations* read: "Failure to complete practical work under cl. 2(i), without good reason, will be deemed by the Moderators as failure in the Preliminary examination and the candidate will be required to complete the outstanding practicals either by examination or by completing them alongside second year study, before entry to the Part A examination will be permitted. In these circumstances, distinction at the Preliminary examination will not be possible."

B: Second and Third Year

The practical mark for the second and third year consists of marks for the experiments, the oral skills exercise and an assessed practical. The relative marks are made up as follows:

	Part A	Part B
Experiments	15	30
Oral Skills	15	-
Assessed Practical	20	20
Total	**50**	**50**

(i) The first **15** marks in Part A and **30** marks in Part B are given for completing all experiments. Failure to complete the practical quota would attract the following penalty: (a) A penalty of 5 marks will be deducted for each missed two-day experiment. (b) If more than 3 two-day experiments are missed the student can drop a class.

(ii) Part A: Oral Skills

In the second year all students give a 15 minute presentation called Oral Skills in their Colleges on a physics topic of their choice.

(iii) Part A and Part B: Assessed Practical

In both the 2nd and 3rd years, one of your practicals will become an "assessed practical". This is marked by a senior demonstrator in a short oral examination carried out in **Trinity Term**. More details can be found in the *Practical Course Handbook*.

Marking Scheme for Oral Skills

- A mark of 15: Students can attract the top mark for exceptional performance for their oral presentation (talk) in college.
- A mark of 12: Students will attract this mark if the oral presentation is regarded as very good.
- A mark of 10: Students will be awarded this mark if the presentation was acceptable and average in quality.
- A mark of 9 or below: Students will be awarded this mark if the presentation is deemed to be below standard.

One student per College, obtaining high marks in Oral Skills in their College talks, may be nominated by their College tutors to participate in the Departmental Speaking Competition. An average student with an average presentation should achieve 10 marks. Students who put in little or no effort can score very low marks.

Marking of the Assessed Practical

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

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

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

Eligibility for MPhys Course

After the Part A examination, the Finals examiners will make known on the Student Self Service the students eligible to proceed to the MPhys course. The standard required is the equivalent of a II.1 Class or better in Part A.

Three or Four year course

Should you be undecided as to which course you should be doing, then in the first instance discuss it with your College tutor. It is not necessary to make up your mind until the start of your third year, but it is generally advisable to register initially for the 4-year MPhys course. Students should realise that the MPhys course is demanding and quite theoretically based.

Students who have passed the hurdle in Part A and are about to start their third year **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 2nd week.** More information can be found at http://www.ox.ac.uk/current_students/index.html. (See also 'Changing from the MPhys to the BA'.)

Examination Preparation

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

Examination Entry

Entry for all examinations in physics [Prelims, FHS Parts A, B (MPhys and BA) and Part C (MPhys)] takes place in two stages.

The first is at the end of 4th week of Hilary Term; the second (for Short Option Choices) is at the end of 3rd week of Trinity Term. The purpose of the exam entry form is to provide exact information on who is taking the exam that year and to record option choices. Entries are made through your College and are usually organised by the College Secretary or College Academic Office, however it is your responsibility to make sure that your entry is made and with the correct option choices and project titles (as appropriate). See http://www.ox.ac.uk/students/exams/ for more information.

Examination Conventions

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

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

Examination Dates

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

Sitting your examination

Information on the standards of conduct expected in examinations and 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

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

Examination Regulations

The regulations for both the Preliminary and Finals Honour School are published in **Appendices H** and **I**. The *Examination Regulations* are published at www.admin.ox.ac.uk/examregs/.

Examination Results

After each part of the examination, your tutor will be told the scaled marks that you obtained in each paper and your overall rank amongst candidates in that part. This information will not be published, but will be provided to enable your tutor to give you some confidential feedback and guidance. Students are now able to view their examination results at http://www.ox.ac.uk/students/exams/results/. Marks displayed in the Student Self Service are given as percentages; e.g. 40 marks for Part A full practicals is entered as 80.

Prizes

Prizes are awarded for excellence in various aspects of the BA and MPhys final examinations including:

- Scott Prizes for overall best performances (separately for BA and MPhys)
- A Gibbs Prize for excellence in the MPhys examination
- The Winton Capital Prize for Outstanding Performance in the 2nd year (Part A examination)
- A Gibbs prize for practical work in Parts A and B
- The Chairman's prize for practical work in Prelims

- Various project prizes for MPhys Projects (some of these may be sponsored by external bodies)
- BA prizes for the BA Project Report and the BA Group Presentation
- A Gibbs Prize for the best performance in the Physics Department Speaking Competition (held in the 2nd year, see page 16).

Past Exam Papers

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

External Examiner and Examiners' Reports

The names of the External examiners are published in the Examination Conventions see https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters. Students are strictly prohibited from contacting external examiners and internal examiners directly. If you are unhappy with an aspect of your assessment you may make a complaint or appeal see http://www.ox.ac.uk/students/academic/appeals.

Physics and Philosophy

There is a corresponding Handbook for this course: *Physics and Philosophy Course Handbook* see http://www2.physics.ox.ac.uk/students/undergraduates. 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*.

The Physics and Philosophy course is run by the Joint Committee for Physics and Philosophy, which consists of two staff members from Physics and Philosophy, together with an undergraduate representative. Please contact Dr Christopher Palmer (christopher.palmer@physics.ox.ac.uk) should you have queries about the Physics and Philosophy course.

Physics and Philosophy is normally a 4 year course. The first year of the course leads to the examination called Prelims, which consists of five papers, three in mathematics and physics and two in philosophy. After successfully completing Prelims, students enter the Final Honour School (FHS) of Physics and Philosophy, which is divided into three parts: Part A, Part B and Part C. Part A of the FHS is taken at the end of the second year, and consists of three papers in physics. Parts B and C are taken at the end of the third and fourth years respectively. Students taking Part B will take three or four philosophy papers and either three or five physics subjects, each carrying the weight of half a paper, chosen from a list of seven: the six Part B physics subjects and a paper on Classical Mechanics (B7: Classical Mechanics). In Part C there are a range of options including all physics or all philosophy.

Students who satisfactorily complete the fourth year may supplicate for the MPhysPhil degree, as determined by their performance in Parts A, B and C of the FHS; those who, for whatever reason, do not wish to proceed to the fourth year, or who begin but do not complete the fourth year or who otherwise fail to complete it satisfactorily, will be eligible for the BA degree, as determined by their performance in Parts A and B of the FHS.

The aims and objectives of the physics course, stated above, apply equally – where appropriate – to the Physics and Philosophy course. Additionally, the aim of the physics components in the Physics and Philosophy course is to provide an appropriate basis for the study of foundational and philosophical aspects of physical science, in particular of quantum mechanics and special relativity.

The physics papers taken by Physics and Philosophy candidates are marked on exactly the same basis as those taken by Physics candidates (please refer to the section on **Examinations**). Guidelines to the assessment criteria in philosophy papers are given in the *Physics and Philosophy Course Handbook*. The overall classified result is derived from the individual marks obtained on your written papers of the FHS, taking Parts A, B and C together. "The highest honours can be obtained by excellence either in Physics or in Philosophy, provided that adequate knowledge is shown in the other subject area" [ref. *Grey Book*].

The Joint Committee for Physics and Philosophy has endorsed an algorithm for determining class boundaries, which is described at https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters

Students should note that they will have to complete, as part of their Part A requirements, four physics practicals during their second year; and make sure their experiments are marked and entered into the computer lab record by a demonstrator. It is compulsory for all **second** year Physics and Philosophy students to attend the Safety Lecture on Monday of 1st week of Michaelmas Term, see page 13. Although there is no requirement for practical work in the first year of the course, it is possible to arrange (through your physics tutor) to do some if you want to, but attending the Safety Lecture during your first year is compulsory in this case.

Summary of Examination Requirements

Physics	Physics and Philosophy
Prelims Four Compulsory Papers CP1, CP2, CP3, CP4 Short Option Paper Satisfactory Practical Work	**Prelims** Three Physics Papers CP1, CP3, CP4 Two Philosophy Papers
Part A Three Compulsory Papers A1, A2, A3 Short Option Paper Part A Practical Work	**Part A** Three Physics Papers A1, A2P, A3 Satisfactory Practical Work
Part B **BA** (3 year Course) Four Papers including B3, B4, B6 and one other, from B1, B2 and B5 Short Option Paper Mini Project Part B Practical Work BA Group Presentation BA Project Report **Part B** **MPhys** (4 year Course) Six Papers: B1, B2, B3, B4, B5 and B6 Short Option Paper Mini Project Part B Practical Work	**Part B** Three or four papers in Philosophy and either three or five physics subjects, each carrying the weight of half a paper, chosen from a list of seven: the six Part B physics subjects and a paper on Classical Mechanics.
Part C Two Papers from C1, C2, C3, C4, C5, C6, C7 MPhys Project Report	**Part C** The details depend on the option route See the *Physics and Philosophy* Handbook

First Year 2015-2016

Induction

Induction
9 October 2015 at 2.15 pm

All Physics and Physics and Philosophy first years are **required** to attend the Induction from 2.15 - 4.15 pm on Friday afternoon of 0^{th} week of Michaelmas Term. There you will hear a brief introduction to Oxford Physics, an outline of the first year course, and addresses by a student representative of the Physics Joint Consultative Committee and by a representative of the Institute of Physics. There will also be an introduction to the Practical Course. The *Practical Course Handbook* is available from http://www2.physics.ox.ac.uk/students/undergraduates

To keep the numbers manageable, students will be split by College into two groups; please check below which group you are in. Group A will start in the Dennis Sciama Lecture Theatre, Denys Wilkinson Building (DWB); Group B in the Martin Wood Lecture Theatre in the Clarendon (see map and directions on the inside cover). All Physics and Philosophy students should join Group B.

Group A (Practicals usually on Thursdays)

Balliol, Brasenose, Exeter, Jesus, Magdalen, Mansfield, Merton, Queen's, Pembroke, St Catherine's, St John's, St Edmund Hall, Wadham, Worcester.

Group B (Practicals usually on Fridays)

Christ Church, Corpus Christi, Hertford, Keble, Lady Margaret Hall, Lincoln, New, Oriel, St Anne's, St Hilda's, St Hugh's, St Peter's, Somerville, Trinity, University.

Please note. This grouping of Colleges also shows which day you will probably do practical work during the first year. (There can be some reassignment to even out numbers.)

Safety Lecture

A safety lecture, which is **compulsory** for all Physics students is held on the Monday of 1^{st} week of Michaelmas Term at 2.00 pm in the Martin Wood lecture theatre. Only those who have attended and signed a safety declaration are allowed to carry out practicals.

If for any reason it is not going to be possible for you to attend, tell your tutor, and let Dr Karen Aplin (karen.aplin@physics.ox.ac.uk) know before the beginning of 1^{st} week.

A DVD is available for those who have been excused because of unavoidable commitments at the advertised time or (for a fee) to those who miss the lecture for other reasons.

Practical Work

During the first two weeks of Michaelmas Term each first-year student will attend sessions introducing some of the test and measurement instruments used on the practical courses, and the computers and computing environment.

Laboratory practical work starts in the third week of Michaelmas Term and takes place between 10.00 am and 5.00 pm on Thursdays and Fridays. Laboratories are allocated on a rota system. Details are given in the *Practical Course Handbook*. You should not arrange commitments that clash with your practical work; however, if the allocation raises genuine difficulties for you, discuss it with your tutor well before your practical work starts.

You MUST prepare for practicals by reading the script before you attend the laboratory. Any student who is not prepared may be asked to leave.

Laboratory introduction
12 October 2015
at 12.00 noon

An introduction to practical work is given on Monday of 1^{st} week at 12.00 noon in the Martin Wood Lecture Theatre. Pairings for practical work will be registered at the Safety lecture. The *Practical Course Handbook* contains all the information you need about this part of the course. It is important to become familiar with it.

Safety Lecture
12 October 2015
at 2.00 pm

Self-study modules in basic mathematics and mechanics

These are designed to bridge the gap between school and university maths, mechanics, statistics and data analysis. Your tutor has more information. See also '*The Language of Physics*' J. P. Cullerne and A. Machacek (Oxford).

Lecture timetables
www.physics.ox.ac.uk/lectures

Prelim Papers

CP1: Physics 1
CP2: Physics 2
CP3: Mathematical Methods 1
CP4: Mathematical Methods 2

Short Options

S01: Functions of a Complex Variable
S02: Astrophysics: from Planets to the Cosmos
S03: Quantum Ideas

The Preliminary Examination

The first year is a foundation year, at the end of which you will take the Preliminary Examination (Prelims). This consists of four compulsory papers [CP1: Physics 1, CP2: Physics 2, CP3: Mathematical Methods 1 and CP4: Mathematical Methods 2], a Short Option and satisfactory practical work. Each of the CP papers will be in two sections: A - containing short compulsory questions; B - containing problems (answer three from a choice of four). The total marks for sections A and B will be 40 and 60, respectively.

For Prelims, one of the Short Options S01, S02 or S03 is chosen. These subjects will be covered by lectures at the start of Trinity Term. There are no resit exams for Short Options and a poor mark will not lead to failure in Prelims, but good performance helps if you are on the borderline of a Pass or a Distinction.

The practical course requirement for Prelims is 17 days credit, made up of practicals, computing assignments and write ups. Candidates failing to complete their practicals will be required to complete them before entry to the Part A, see page 9.

The Compulsory Papers are individually classified as Pass and Fail, with a Pass mark of 40%. The examiners will take into account the performance in the whole examination (the four Compulsory Papers, the Short Option paper and Practical Work) when considering the award of a Distinction and when considering borderline scripts.

Introduction to Computer Programming

During the first half of Michaelmas Term, there will be introductory lectures on computer programming which will be coupled with the practical sessions on computing.

The Department has site licences for several powerful data analysis and mathematical software packages. See the *Practical Course Handbook* or the website for more information and how to download the software.

Textbooks

A list of the books recommended by the lecturers is given in **Appendix A**. Your tutor will advise you as to what books you should obtain. A guide to library services is given on page 4.

First Year Physics and Maths Lectures

The syllabuses for papers CP1- 4 are given in **Appendix C** and those for the Short Options in **Appendix F**. The timetable of all the lectures for Prelims is published in the Departments's *Lecture Database* on the Web, under *Physics Lecture List*.

Lectures start promptly at five minutes past the hour and end at five to.

On the page 15 there is a brief overview of the first year lectures. As well as the lectures on the mainstream topics shown, there are others on the list that should be attended; those on the analysis of experimental measurements contain important material for the practical course.

Examination Entry

Entry for the Prelims exam is at the end of 4th week of Hilary Term and 3rd week of Trinity Term for Short Option choices. Specific details will be published by the Examiners.

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

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

Physics and Philosophy

The first year course leads to the Preliminary examination in Physics and Philosophy, in which you take papers CP1, CP3 & CP4. The syllabuses for these papers are given in **Appendix C**. See the *Physics and Philosophy Course Handbook* for further details about Prelims, including details of the Philosophy papers.

First Year Outline of Topics

For definitive details see the Physics Department's *Lecture Database* (www.physics.ox.ac.uk/lectures/).

Lecture timetables
www.physics.ox.ac.uk /lectures/

Below is a brief outline of the mainstream topics that will be lectured in Michaelmas, Hilary and Trinity Terms. Most Colleges are able to do two classes or tutorials per week. Tutorials are done in pairs, or sometimes in threes. Classes are normally made up of all the students in that year in a College. There is approximately one tutorial or class per 4 lectures. As a guide, about 8 hours of independent study are expected for each hour of tutorial or class teaching.

Michaelmas Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[CP1:Mechanics ----------]								9
			[CP1:Special Relativity ----------]					10
				[CP2: Circuit Theory ----------]				10
	[CP2: Optics -------]							7
[CP3: Vectors and Matrices ----------]								22
			[CP3: Complex Numbers & ODEs]					10
[CP4: Calculus ----------]								11
[Extras ----------]								11

Prelims Papers

CP1: Physics 1
CP2: Physics 2
CP3: Mathematical Methods 1
CP4: Mathematical Methods 2

Hilary Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[CP1:Mechanics ----------]								20
[CP2: Electromagnetism ----------]								20
						[CP2: Optics ------]		4
[CP4: Multiple Int/Vector Calc ----------]								14
[CP4:Normal Modes and Wave Motion ----------]								12

Prelims Papers

CP1: Physics 1
CP2: Physics 2
CP3: Mathematical Methods 1
CP4: Mathematical Methods 2

Trinity Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[CP1: Revision -----]								4
		[CP2: Revision -----]						4
[CP3: Revision -----]								4
		[CP4: Revision -----]						4
[S01: Functions of a Complex Variable--]								12
[S02: Astrophysics ----------]								12
[S03: Quantum Ideas ----------]								12

Prelims Papers

CP Revison

Short Options

S01: Functions of a Complex Variable
S02: Astrophysics: from Planets to the Cosmos
S03: Quantum Ideas

Second Year 2015-2016

Introduction to 2nd year
12 October 2015

Part A Papers

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

Short Options
see page 28

Physics Department Speaking Competition

Teaching and Learning Physics in Schools

14 October 2015

The BA and MPhys courses

Part A is the same for the BA (3-year) and MPhys (4-year) courses. The examinations will take place at the end of Trinity Term and consists of three papers: A1: *Thermal Physics*; A2: *Electromagnetism and Optics*; and A3: *Quantum Physics*. The material will be covered by lectures, tutorials and classes concentrated in Michaelmas Term and Hilary Term. Full details of the syllabuses are given in **Appendix D**. Each of the A papers will be divided into two sections: A containing short compulsory questions and B containing problems (answer three from a choice of four). Total marks for sections A and B will be 40 and 60 respectively. In addition you are required to offer at least one short option together with Part A practical work including Oral Skills.

Practical Work including Oral Skills

The requirement for practical work for Part A is 12 days (8 days in Michaelmas Term and 2 days in Hilary Term for electronics only, and 2 days in Trinity Term, weeks 3 & 4). It is possible to substitute 6 days of practical work with alternatives as explained opposite. There is also an assessed practical, see page 9.

The *Practical Course Handbook* and https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/exammatters will contain details of the handling of logbooks.

There will be a lecture at the end of Michaelmas term giving guidance on how to give a talk (see the Michaelmas Term lecture list) in preparation for the short talk each student will be required to do within Colleges. This talk is usually given in Hilary Term as training in oral communication skills.

The Oral Skills talks should be written to last 15 minutes, with a further 5 minutes allowed for questions. Topics on any branch of science and mathematics or the history of science may be chosen, but your title must be approved by your College tutor. Your tutor will mark your talk out of a maximum of 15 marks. See page 9 for the marking scheme.

Physics Department Speaking Competition

The Departmental Competition is held early in Trinity Term. College tutors may nominate one student to enter for this competition.

Each entrant will be allowed a maximum of ten (10) minutes for the presentation and up to two (2) minutes for questions. Students using PowerPoint slides must provide the Teaching Faculty Office with their presentation 24 hours before the competition.

The winner of the Department's competition may be eligible for a prize. Examples of these talks can be found at https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/oralskills to give students an idea of what a good talk should be like. Please note that the talks are meant to be technical and must include scientific or mathematical content.

Short Options & Language Option

Details on the Short Options (including the Language Option) are given on page 28. It is possible to offer a second Short Option in place of 6 days of practical work.

Alternative subjects, extra practicals and extended practicals

Given the necessary permission, it is also possible to offer alternative subjects, extra practicals or an extended practical in place of the compulsory Short Option. Details are given on page 28.

Teaching and Learning Physics in Schools

This popular option is offered to 2nd year physics undergraduates in Hilary Term and is run jointly by the Department of Physics and the Department of Education. The eight (8) seminars provide students with an opportunity to explore key issues in physics education, looking at evidence from physics education research and discussing current developments in policy and practice. Students also spend six (6) days in local secondary schools, working closely with experienced physics teachers in lessons and gaining valuable insights into schools from the teachers' perspective.

An introductory lecture is given at 11 am in the Lindemann Theatre on Wednesday 1st week Michaelmas Term to which all interested students are invited. Those wishing to take the option are asked to submit a piece of writing (one side of A4) by Friday 2nd week Michaelmas Term to Dr Judith Hillier (judith.hillier@education.ox.ac.uk) on

(a) why it is important to teach physics and (b) why the student wants to be accepted onto the option.

A modified version of the course is available for Physics and Philosophy students.

Teaching and Learning Physics can only be offered as a second short option.

Undergraduate Physics Conference

Undergraduate Physics Conference
www.physics.ox.ac.uk/users/palmerc/oupc.htm

This conference is an annual event held in 0th week of Trinity Term for second and third year students. There is a small fee for attendance, for which students may apply to their Colleges, with bookings being taken from the beginning of Hilary. For more details see www.physics.ox.ac.uk/users/palmerc/oupc.htm.

Examination Entry

Entry for the FHS Part A exam is at the end of 4th week of Hilary Term, and 3rd week of Trinity Term for Short Option choices (except for certain alternatives). Specific details will be published by the Examiners.

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

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

Eligibility for MPhys Course

After the Part A examination, the Finals examiners will make known on the Student Self Service the students eligible to proceed to the MPhys course. The standard required is the equivalent of a II.1 Class or better in Part A. Those students who are not eligible for the MPhys course must take the 3-year BA course.

Physics and Philosophy

Part A is examined at the end of Trinity Term and consists of three Physics papers: A1: *Thermal Physics* and A3: *Quantum Physics* from Physics Part A with syllabuses given in **Appendix D** and a short paper A2P: *Electromagnetism* from the Physics Prelims syllabus (paper CP2 **without** the topics in circuit theory or optics - **Appendix C**). You should also attend the 20-lecture course in Michaelmas Term on Mathematical Methods (See **Appendix D** for the syllabus).

There are no philosophy papers in Part A. The philosophy covered in both the second and third years (for details see the *Physics and Philosophy Course Handbook*) is examined in Part B at the end of the third year.

The three part A papers taken together have a weight for the purposes of the Finals algorithm of 2, made up of ¾ for A1 and A3 and ½ for A2P.

For the experimental requirements in Physics and Philosophy Finals Part A, four physics practicals **must** be completed by the end of your second year. See the *Practical Course Handbook* for more details.

There will be a lecture at the end of Michaelmas term giving guidance on how to give a talk (see the Michaelmas Term lecture list) in preparation for the short talk each student will be required to do within Colleges. This talk is usually given in Hilary Term as training in oral communication skills.

A modified version of the Physics in Schools option is available to P&P as an alternative to the oral skills training - interested students should attend the introductory lecture in 1st week. The Physics in Schools option cannot replace the compulsory practical work requirement.

You have to attend the 1st year 'Introduction to Practicals' and the Safety Lecture at the beginning of your **second** year. Only students who are recorded as having attended the Safety Lecture are allowed to carry out practicals.

Second Year Outline of Topics

For definitive details see the Physics Department's *Lecture Database* (www.physics.ox.ac.uk/lectures/).

Lecture timetables

http://www.physics.ox.ac.uk/lectures/

Below is a brief outline of the mainstream topics that will be lectured in Michaelmas, Hilary and Trinity Terms. Most Colleges are able to do two classes or tutorials per week. Tutorials are done in pairs, or sometimes in threes. Classes are normally made up of all the students in that year in a College. There is approximately one tutorial or class per 4 lectures. As a guide, about 8 hours of independent study are expected for each hour of tutorial or class teaching.

Part A Papers

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

Michaelmas Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[Analogue Electronics]								4
		[A1: Statistical and Thermal Physics --------------------------]						15
[A2: Electromagnetism--]								20
				[A3: Quantum Mechanics -------------]				12
[S20: History of Science ---]								8
[Probability and Statistics]								6
[Mathematical Methods--]								20
[Extras ---]								2

Part A Papers

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

S07: Classical Mechanics

Hilary Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[A1: Statistical and Thermal Physics ------------------------------]								24
[A2: Optics --]								16
[A3: Quantum Mechanics ---------------------------]								15
				[A3: Further Quantum Physics]				9
[S07: Classical Mechanics ---]								16
[S21: Philosophy of Science ---]								8
[S27: Philosophy of Space Time --------------------------------------]								8
[Extras --]								1

A3: Quantum Physics

Short Options

Trinity Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[A3: Further Quantum Physics]								11
[S01: Functions of a Complex Variable]								12
[S02: Astrophysics: from Planets to the Cosmos]								12
[S04: Energy Studies --------------]								12
[S12: Introduction to Biological Physics]								12
[S22: Language Options]								8
[S26: Stars and Galaxies								12
[S29: Exploring Solar Systems								12
[Extras -------------------------------------]								5

Third Year 2015-2016 [BA Course]

Introduction to 3rd year
12 October 2015

BA Course

The BA course is a 3 year course and students study four subjects, undertake practical work, and carry out a group project which provides the material for their individual project report.

Part B Examination

The examination will take place at the end of Trinity and consists of four papers, a Short Option paper, a mini project, practical work, BA Group Presentation and a BA Project report. The four papers are chosen from the six (6) B papers of the 3rd year of the MPhys course: B1: *Flows, Fluctuations and Complexity*, B2: *Symmetry and Relativity,* B3: *Quantum, Atomic and Molecular Physics*, B4: *Sub-Atomic Physics,* B5*: General Relativity and Cosmology* and B6*: Condensed-Matter Physics* ***and*** **must** include B3, B4 and B6. The material will be covered by lectures, tutorials and classes concentrated in Michaelmas & Hilary of the third year. Full details of the syllabuses are given in **Appendix E.**

Part B Papers

B1: Flows, Fluctuations and Complexity

B2: Symmetry and Relativity

B3: Quantum, Atomic and Molecular Physics

B4: Sub-Atomic Physics

B5: General Relativity and Cosmology

B6: Condensed-Matter Physics

Practical Work including mini project

Part B Practical

The official requirement for practical work for Part B is 12 days (usually 8 days in Michaelmas and 4 days in Trinity). 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. Note that the "official" requirement for the examiners includes two extra days of credit given for the mini-project, which is not included in the MS record.

It is possible to substitute for 6 days of practical work, by taking a second short option, but you must carry out a mini project plus one other 2 day practical. There is also an assessed practical, see page 9.

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

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

BA Project

BA Project Introductory lecture
13 October 2015 at 9 am

BA Project

The Group Industrial Project is compulsory for all third year students who are registered on the BA course. Students will be organised into groups of 4-6 to work on a physics-related problem set by an external company, with the support of an external industrial mentor and an internal academic supervisor.

There will be an introductory lecture on BA projects on 13 October at 9am.

The group project is assessed in two ways: (i) a group presentation in Hilary Term on Wednesday afternoon of 4th week, for which each group member is awarded the same mark, by a marking panel, and (ii) a mark for your individual contribution to the team, based on a report.

More details will be announced at the introductory lecture and can be found on www.physics.ox.ac.uk/students/undergraduates/third-year-group-projects. This contains the project timetable and deadlines, plus information on report requirements.

Project Safety

There is a compulsory Safety Lecture in 1st week of Michaelmas, which all third year BA students **MUST** attend.

Submitting the report at Examination Schools

Three (3) copies of the report with a declaration of authorship and a copy of the report in pdf format on a CD must be handed in to the Examination Schools by Monday of 1st week of Trinity Term.

Short Options & Language Option

Short Options

Details of the Short Options (and alternatives) are given on page 27. It is possible to offer a second Short Option in place of 6 days of practical work.

Alternative subjects, extra practicals and extended practicals

Given the necessary permission, it is also possible to offer alternatives in place of the Short Option. Details are given on page 28.

Undergraduate Physics Conference
www.physics.ox.ac.uk/users/palmerc/oupc.htm

Undergraduate Physics Conference

This conference is an annual event held in 0^{th} week of Trinity Term for second and third year students. There is a small fee, for which students may apply to their College, for attendance with bookings being taken from the beginning of Hilary. For more details see www.physics.ox.ac.uk/users/palmerc/oupc.htm.

Examination Entry

Entry for the Part B exam is at the end of 4^{th} week of Hilary Term and 3^{rd} week of Trinity Term for Short Option choices (except for certain alternatives). Specific details will be published by the Examiners.

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

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

Third Year 2015-2016 [MPhys Course]

Choice of Course

During Michaelmas, you must decide whether you will take the three year course (BA) or the four year course (MPhys). Your tutor will have received the results of your Part A examination over the long vacation, and if you have any doubts concerning which course you should take you should discuss the situation carefully with your tutor in the light of your examination results. After the Part A examination, the Finals examiners will make known on the Student Self Service the students eligible to proceed to the MPhys course. The standard required is the equivalent of a II.1 Class or better in Part A. Those students who are not eligible for the MPhys course must take the 3-year BA course.

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

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

Part B Examination

Part B Papers
B1: Flows, Fluctuations and Complexity
B2: Symmetry and Relativity
B3: Quantum, Atomic and Molecular Physics
B4: Sub-Atomic Physics
B5: General Relativity and Cosmology
B6: Condensed-Matter Physics

The examination will take place at the end of Trinity Term and consist of six papers: B1: *Flows, Fluctuations and Complexity*, B2: *Symmetry and Relativity,* B3: *Quantum, Atomic and Molecular Physics*, B4: *Sub-Atomic Physics,* B5*: General Relativity and Cosmology* and B6*: Condensed-Matter Physics*. The material will be covered by lectures, tutorials and classes concentrated in Michaelmas & Hilary of the third year. Full details of the syllabuses are given in **Appendix E**.

Practical Work including mini-project

Mini project

The official requirement for practical work for Part B is 12 days (usually 8 days in Michaelmas and 4 days in Trinity). 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. Note that the "official" requirement for the examiners includes two extra days of credit given for the mini-project, which is not included in the MS record.

Part B Practical

It is possible to substitute for 6 days of practical work, by taking a second short option, but you must carry out a mini project plus one other 2 day practical. There is also an assessed practical, see page 9.

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

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

Short Options & Language Option

Introduction to 3^{rd} year
12 October 2015

Short Options
Language Option

Details of the Short Options (and alternatives) are given on page 27. It is possible to offer a second Short Option in place of 6 days of practical work.

Project Safety

There is a compulsory Safety Lecture in 1^{st} week of Michaelmas, which all third year MPhys students **MUST** attend.

Alternative subjects, extra practicals and extended practicals

Given the necessary permission, it is also possible to offer alternative subjects or an account of extra practicals or an extended practical in place of the compulsory Short Option. Details are given on page 28.

Changing from the MPhys to the BA (MPhys Exit)

Students who have passed the hurdle in Part A and are about to start their third year must make the decision about doing the BA or MPhys course by

(i) the beginning of MT 0^{th} week with a firm deadline of Friday noon of 2^{nd} week. Students thinking of taking the BA course, but undecided by MT 0^{th} week, should tentatively sign up for a BA group project so that they can be assigned one at the start of term.

(ii) If you want to change to the BA after the deadline of Friday noon of 2nd week, you can only exit after the 3rd year examinations i.e. Part B **and not** during the course of the third year.

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

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

Undergraduate Physics Conference

Undergraduate Physics Conference

This conference is an annual event held in 0th week of Trinity Term for second and third year students. There is a small fee for attendance, for which students may apply to their College, with bookings being taken from the beginning of Hilary. For more details see www.physics.ox.ac.uk/users/palmerc/oupc.htm.

Major Options

Physics and Philosophy

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 return a form indicating your 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 the Physics Teaching Faculty via the Assistant Head of Teaching (Academic) by e-mail to carrie.leonard-mcintyre@physics.ox.ac.uk in Trinity Term of your third year.

Examination Entry

Entry for the FHS Part B exam is at the end of 4th week of Hilary Term, and 3rd week of Trinity Term for Short Option choices (except for certain alternatives). Specific details will be published by the Examiners.

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

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

Physics and Philosophy

The physics component in Part B consists of three (or five if your elective paper is in physics) subjects drawn from the following list:

- B1: Fluctuations, flows and complexity
- B2: Symmetry and relativity
- B3: Quantum, atomic and molecular physics
- B4: Sub-atomic physics
- B5: General Relativity and cosmology
- B6: Condensed-matter physics
- B7: Classical mechanics

Your selection must include at least two of the subjects B2, B5 and B7.
Papers B1-B6 are the same as the core Part B physics papers taken by MPhys students, which are examined in six 2-hour papers, as shown above. The B7 paper is specially set for P&P students, in the same format as the other six subjects in Part B, and 2 hours in length. You should have tutorials to prepare you for this paper.

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

MMathPhys

We offer a taught masters course in Mathematical and Theoretical Physics, see http://mmathphys.physics.ox.ac.uk

Third Year Outline of Topics

For definitive details see the Physics Department's *Lecture Database* (www.physics.ox.ac.uk/lectures/).

Below is a brief outline of the mainstream topics that will be lectured in Michaelmas, Hilary and Trinity Terms. Tutorials are done in pairs, or sometimes in threes. Classes are normally made up of all the students in that year in a College. There is approximately one tutorial or class per 5 lectures. As a guide, about 10 hours of independent study are expected for each hour of tutorial or class teaching.

Lecture timetables

www.physics.ox.ac.uk/lectures/

Michaelmas Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[B1: Flows, Fluctuations and Complexity --------]								22
[B2: Symmetry and Relativity--------]								22
[B3: Quantum, Atomic and Molecular Physics --------]								22
[S20: History of Science --------]								8
[S28: Philosophy of Quantum Mechanics]								16
[Extras --------]								2

Hilary Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[B4: Sub-Atomic Physics --------]								22
[B5: General Relativity and Cosmology --------]								22
[B6: Condensed-Matter Physics --------]								22
[S07:Classical Mechanics --------]								16
			[S18:Advanced Quantum Mechanics --------]					12
[S21: Philosophy of Science --------]								8
[S27: Philosophy of Space Time --------]								8
[Extras--------]								1

Trinity Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[B1: Flows, Fluctuations and Complexity]								2
[B2: Symmetry and Relativity--------]								2
[B3: Quantum, Atomic and Molecular Physics]								2
[B4: Sub-Atomic Physics--------]								2
[B5: General Relativity and Cosmology-]								2
[B6: Condensed-Matter Physics --------]								2
[S01: Functions of a Complex Variable]								12
[S04: Enery Studies]								12
[S12: Introduction to Biological Physics]								12
[S16: Plasma Physics --------]								12
[S19: Unifying Physics Accelerators, Lasers and Plasma]								12
[S22: Language Options--------]								8
[S26: Stars and Galaxies]								12
[S29: Exploring Solar Systems]								12

Part B Papers

B1: Flows, Fluctuations and Complexity

B2: Symmetry and Relativity

B3: Quantum, Atomic and Molecular Physics

B4: Sub-Atomic Physics

B5: General Relativity and Cosmology

B6: Condensed-Matter Physics

Short Options

Mini-project

BA Group Presentation

BA Projects

Fourth Year 2015-2016 [MPhys Course]

Part C Finals for the 4-year MPhys

In Trinity Term, you are required to take two Major Options papers of your choice (see **Appendix G**). These papers together with a project form Finals Part C for the MPhys course. Although you will have made a considered preliminary choice of options in Trinity Term of your third year, you may revise that choice at the start of Michaelmas Term.

Major Options

Two Major Options

If you wish to change, or have not yet indicated your choice, it is essential that you inform the Assistant Head of Teaching (Academic) **no later than Friday of 0th week of Michaelmas** (see http://www2.physics.ox.ac.uk/students).

Alternative Major Options

Lectures and Classes for the Major Options

MPhys Projects

The lectures for the Major Options take place from the start of Michaelmas Term until the middle of Trinity Term. The lecture courses cover the material given in the syllabuses in **Appendix G** at the back of the handbook.

For each option there will be a total of 8 classes, distributed roughly as follows: 3 classes in Michaelmas, 3 classes in Hilary and 2 classes in Trinity. More details on the Major Options are given via the Physics web page http://www2.physics.ox.ac.uk/students.

The Major Options available are:

- C1: Astrophysics
- C2: Laser Science and Quantum Information Processing
- C3: Condensed Matter Physics
- C4: Particle Physics
- C5: Physics of Atmospheres and Oceans
- C6: Theoretical Physics
- C7: Biological Physics

The lectures are an integral part of the Major Options and as such you are strongly advised to attend all lectures. Classes will be treated like tutorials and any absence, or failure to submit written work, will be reported to your College.

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. See the Examination Regulations on page 51.

Permission must be sought from the Head of the Physics Teaching Faculty in Trinity Term of your third year via the Assistant Head of Teaching (Academic) by e-mail at carrie.leonard-mcintyre@physics.ox.ac.uk. Students will be advised of the decision by the start of Michaelmas Term at the latest.

Projects

Projects are carried out during Michaelmas and Hilary Terms. **There is a compulsory Safety Lecture in 1st week of Michaelmas Term, which all MPhys students must attend.** The *MPhys Projects Trinity Term* 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 noon on Friday of **6th** week, of Trinity Term.

MPhys Project Guidance published at http://www2.physics.ox.ac.uk/students/undergraduates/mphys-projects will contain a timetable for carrying out the project work and handing in the report. The allocation of projects will be published by mid-September, **S**tudents must then contact their supervisor to discuss the preparation for the project work.

Three (3) copies of the final report with a declaration of authorship and a copy of the report in pdf format on a CD must be handed in to the Examination Schools by Monday of 1st week of Trinity Term. See the *MPhys Project Guidance* for more details.

Exam Entry

Entry for the MPhys Part C exam is at the end of 4th week of Hilary Term (choice of Major Options and a project title). Specific details will be published by the Examiners.

The *Examination Regulations* provides guidance for students with special examination

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

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

Physics and Philosophy

The fourth year comprises Part C of the FHS. The examination is in the latter part of Trinity Term in both disciplines. Candidates will be required to offer three units in Physics or Philosophy, chosen in any combination from the lists for Physics and for Philosophy. Each unit has a weight of 1⅓ for the purposes of the Finals algorithm, giving a total weight 11½ for Parts A, B and C.

A unit in Physics consists of either a written paper on a Physics Major Option, or a project report on either advanced practical work or other advanced work. The Physics Major Options and the Projects are those specified on page 24 and in the *MPhys Project Guidance* published at http://www2.physics.ox.ac.uk/students/undergraduates/mphys-projects. Syllabuses for the Physics Major Options are given in **Appendix G**.

Physics and Philosophy

A unit in Philosophy consists of one of the permitted philosophy papers together with a submitted essay on a topic from the paper, or a philosophy thesis. For details see the *Physics and Philosophy Course Handbook*.

If you wish to offer a physics project, please refer to the note on page 24 about project allocation etc., and most importantly, **you must attend the Safety Lecture in 1st week of Michaelmas Term if you intend to do an experimental project.**

Fourth Year Outline of Topics

For definitive details see the Physics Department's *Lecture Database* (www.physics.ox.ac.uk/lectures/).

Lecture timetables

www.physics.ox.ac.uk /lectures/

Below is a brief outline of the mainstream topics that will be lectured in Michaelmas, Hilary and Trinity Terms. Each physics Major Option is usually supported by 8 classes. Typically a class size is 8 students. As a guide, about 10 hours of independent study is expected for each hour of tutorial or class teaching.

Fourth Year

Michaelmas Term: week by week

Part C Papers

MPhys Projects

1	2	3	4	5	6	7	8	No. of lectures
[C1: Astrophysics ---]								16
[C2: Lasers and Quantum Information Processing ---]								18
[C3: Condensed Matter Physics ---]								20
[C4: Particle Physics ---]								19
[C5: Physics of Atmospheres and Oceans ---]								21
[C6: Theoretical Physics ---]								24
[C7: Biological Physics---]								24

Hilary Term: week by week

Part C Papers

MPhys Projects

1	2	3	4	5	6	7	8	No. of lectures
[C1: Astrophysics ---]								17
[C2: Lasers and Quantum Information Processing ---]								16
[C3: Condensed Matter Physics ---]								7
[C4: Particle Physics ---]								16
[C5: Physics of Atmospheres and Oceans ---]								11
[C6: Theoretical Physics ---]								16
[C7: Biological Physics---]								10

Part C Papers

Trinity Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[C1: Astrophysics ---]								8
[C2: Lasers and Quantum Information Processing ---]								8
[C3: Condensed Matter Physics ---]								13
[C4: Particle Physics ---]								8
[C5: Physics of Atmospheres and Oceans ---]								10
[C6: Theoretical Physics ---]								0
[C7: Biological Physics---]								8

Short Options 2015-2016, Language Options & Alternatives

The intended Short Options for the academic year 2015/16 are listed below. Each Physics short option is covered by 12 lectures and examined in a 1½ hour paper. The syllabuses for the Short Options are given in **Appendix F**.

The column labelled 'Years' indicates the year or years in which it would be most appropriate to take the option (based on assumed prior knowledge). Some Short Options will be offered in alternate years: this came into effect from Trinity 2012.

If in doubt, consult your tutor or the option lecturer(s). **A Short Option subject may only be offered once, except the Language Option provided it is a different language**.

Physics Short Options

Code	Title	Years	Notes	Term
S01	Functions of a Complex Variable	1 2 3	(a)	TT
S02	Astrophysics: from Planets to the Cosmos	1 2	(a),(c)	TT
S03	Quantum Ideas	1 only	(a),(c)	TT
S04	Energy Studies	2 3	(b)	TT
S07	Classical Mechanics	2 3	(a)	HT
S12	Introduction to Biological Physics	2 3	(a)	TT
S16	Plasma Physics	3	(a)	TT
S18	Advanced Quantum Mechanics	3	(a)	HT
S19	Unifying Physics of Accelerators, Lasers and Plasma	3	(g)	TT
S26	Stars and Galaxies	2 3	(b)	TT
S29	Exploring Solar Systems	2 3	(b)	TT

From other Departments or Faculties

Code	Title	Years	Notes	Term
S13	Teaching and Learning Physics in Schools	2	(c),(f)	HT
S20	History of Science	2 3	(d)	MT
S21	Philosophy of Science	2 3	(d)	HT
S22	Language Option (French and, Spanish or German)	2 3	(e)	TT
S27	Philosophy of Space-Time	2 3	(d)	HT
S28	Philosophy of Quantum Mechanics	3	(d)	MT

Note:

(a) This Short Option will be offered every year

(b) This Short Option will be offered in Trinity 2016 not in 2017.

(c) May only be taken in the years indicated.

(d) These subjects are pre-approved. The examination for these options are taken in either Michaelmas or Hilary or Trinity Term.

(e) Subject to passing the preliminary test in Hilary Term.

(f) This Short Option may only be offered as a second short option.

(g) This Short Option will be offered in Trinity 2016.

Physics Short Options for 2016-2017

Code	Title	Years	Notes	Term
S10	Medical Imaging and Radiation Therapy	2 3	(b)	TT
S25	Physics of Climate Change	2 3	(b)	TT
S30	Exoplanets	2 3	(b)	TT

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.

Prelims

Choose from one of the Short Options S01, S02 or S03. The Short Option in Prelims is not subject to a resit, but is a required part of the examination and a good performance will help if you are on the borderline of a Pass or Distinction.

Parts A & B

At least one Short Option must be offered in Parts A & B (for both courses). Alternatives, including the Language Option, are available.

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

At the start of Michaelmas Term, meetings will be held for the 2nd and 3rd years to explain the options and choices open to them with regard to Short Options, Practical Work and alternatives. Details about times and places will be announced in the Lecture List.

Language Option

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

A course is offered in French every year. Courses in German or Spanish are offered in alternate years. In Trinity Term 2016, the language courses will be French and Spanish. The minimum entry requirement is normally an A at GCSE in the relevant language or equivalent.

There will be a presentation for those interested in taking a language option at the Language Centre, 12 Woodstock Road on the Friday of 4th week, Michaelmas Term, at 3.00 pm.

Formal application is to the Head of the Physics Teaching Faculty Teaching Faculty by students intending to take a language option is required by Friday of 6th week Michaelmas Term. There is a preliminary test in the middle of Hilary Term to determine eligibility to take this option. The *Examination Regulations* reads: "Approval shall not be given to candidates who have, at the start of the course, already acquired demonstrable skills exceeding the target learning outcomes in the chosen language".

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

For further information, contact the Physics Teaching Faculty (see **Appendix N**) or Dr Robert Vanderplank at the Language Centre (robert.vanderplank@lang.ox.ac.uk).

Students may offer to do the language option on more than one occasion provided it is different language. For example a student can do French in Part A and German in Part B, subject to eligibility to take this option by the preliminary test in the middle of Hilary Term.

Alternative subjects

Application must be made via the Assistant Head of Teaching (Academic) by e-mail to carrie.leonard-mcintyre@physics.ox.ac.uk to replace the compulsory Short Option paper in Part A or Part B; the deadline is Friday of 4th week Michaelmas Term. The application will only be agreed if the proposed course and an examination paper already exists within the University, and the alternative subject is considered appropriate. Students will be advised of the decision by the end of 8th week of Michaelmas Term.

Pre-approved subjects

Several alternative subjects offered by other faculties or departments can be studied in place of one or two short options have been pre-approved as follows:

(i) History and Philosophy of Science: this Supplementary Subject is a paper offered within the University by other departments. Physics students may substitute such a paper instead of two short options. Students may also take either the History of Science or Philosophy of Science as a short option.

(ii) Anyone wishing to do the S20: History of Science course should attend the first lecture, to be given in the Tanner Room, Linacre College, see the Physics *Lecture list* at http://www.physics.ox.ac.uk/lectures/default.aspx

It is especially important to be present at the first lecture, immediately after which tutorial groups for the term will be arranged. Please contact Prof. P. Corsi (pietro.corsi@history.ox.ac.uk). More details can be found at http://www.chem.ox.ac.uk/teaching/sshistory.html. If you wish to offer this option, please inform the Assistant Head of Teaching (Academic) by e-mail at carrie.leonard-mcintyre@physics.ox.ac.uk by 2nd week of Michaelmas Term.

(iii) S21: Philosophy of Science, S27: Philosophy of Space-Time and S28: Philosophy of Quantum Mechanics, can be taken separately to replace one short option. These options are offered by the Philosophy Faculty. If you wish to offer these options, please inform the Assistant Head of Teaching (Academic) by e-mail at carrie.leonard-mcintyre@physics.ox.ac.uk.

Please note: Students must seek permission from their College tutors to study these topics as there will be a financial cost for classes and/or tutorials. The examination dates for the History and Philosophy of Science, S20: History of Science, S21: Philosophy of Physics, S27: Philosophy of Space-Time and S28: Philosophy of Quantum Mechanics are different from the Physics Short Option examination date. No examination results will be released before the completion of all the Physics examinations.

Extra practical work

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

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

(a) Extra practicals

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

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

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

(b) Extended practical

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 contact Dr Karen Aplin (karen.aplin@physics.ox.ac.uk) once you have decided which area of physics you would like to work in. Students must submit one printed copy and an electronic copy (by e-mail attachment) of their report to the Physics Teaching Faculty Office. **Neither** Examination Schools **NOR** the Physics Teaching Laboratories will accept your reports, before noon on Monday of 6th week of Trinity Term. All work submitted will be checked with Tunititin.

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

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

Assessment of extra practical work

The marking of the extra practicals and extended practicals is done using the following categories:

- 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, writing style, and clear diagrams/plots and references will also be taken into account.
- Penalites for late work will be published in the Examination Conventions.

Alternatives to practical work

It is possible to replace some of the practical quota by reports on Physics-related vacation placements, by taking an extra short option, or for Part A students, to take an option related to teaching Physics in schools.

(a) Vacation placements

Work carried out during a vacation placement may be submitted for practical course credit. Should you wish to gain credit for vacation work, you must firstly apply for approval to the Head of Physics Teaching Faculty (TeachingAdmin@physics.ox.ac.uk) after the placement by returning the form AD12 at http://www-teaching.physics.ox.ac.uk/practical_course/Admin/AD12.pdf — project substitution for practical work in Michaelmas term before noon on Friday of 4th week of Michaelmas

Term. It is possible to submit vacation work for practical credit in both Parts A and B, providing that the projects are distinct pieces of work.

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

Teaching and Learning Physics in Schools

This popular option is offered to 2nd year physics undergraduates in Hilary Term and is run jointly by the Department of Physics and the Department of Education. The eight (8) seminars provide students with an opportunity to explore key issues in physics education, looking at evidence from physics education research and discussing current developments in policy and practice. Students also spend six (6) days in local secondary schools, working closely with experienced physics teachers in lessons and gaining valuable insights into schools from the teachers' perspective.

An introductory lecture is given at 11 am in the Lindemann Theatre on Wednesday 1st week Michaelmas Term to which all interested students are invited. Those wishing to take the option are asked to submit a piece of writing (one side of A4) by Friday 2nd week Michaelmas Term to Dr Judith Hillier (judith.hillier@education.ox.ac.uk) on

(a) why it is important to teach physics and

(b) why the student wants to be accepted onto the option.

Assessment is in the form of a 5 minute presentation, given on Monday 8th week Hilary Term, and a 3000 word essay, submitted on Friday 1st week Trinity Term. Guidance and support are given as to the literature to be drawn on and the data to be collected for the assignment. **Teaching and Learning Physics in Schools can only be offered as a second short option. Students doing this option will be given an additional 2 days of practical 'relief'.** A prize will be awarded to the student presenting the best work in this option.

"Teaching Physics in Schools" is ideal preparation for any student contemplating a career in teaching after graduation. It is also very valuable for anyone intending to pursue a career in the wider field of education or a career which requires good teamwork and both written and verbal communication skills.

It is anticipated that students should know whether or not they have been successful in obtaining a place on this option by Friday 3rd week Michaelmas Term. Occasionally there are delays allocating students to this option, in which case you should carry on with your practical work as usual to prevent you from falling behind if you are not selected – ideally making a start on the compulsory Electronics experiments so that you can get them finished in good time. If you end up doing extra practical work as a result of this delay, then the Part A Assessed Practical will be chosen from your highest graded practicals.

Examination Entry

For Prelims and FHS (Final Honours School) Parts A & B, examination entry for Physics Short Options is at the end of 3rd week of Trinity Term. Specific details regarding the examinations will be published by the Examiners.

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.

APPENDIX A

Recommended Textbooks

(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

Short Options

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

S02: Astrophysics:from planets to the cosmos (suitable for 1st and 2nd years)

'Introductory Astronomy & Astrophysics', Zeilek & Gregory
'Universe', Kaufmann & Freedman

S03: Quantum Ideas

'QED', R P Feynman (Penguin)
'Quantum Theory: A Very Short Introduction', J. Polkinghorne (OUP)
'The New Quantum Universe', T. Hey and P. Walters (CUP)
'The Strange World of Quantum Mechanics', Daniel F. Styer (CUP)

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**

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

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)

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.Zeldovich, (World Scientific, 1998)
"Quantum Theory of Scattering", T.Wu and T.Ohmura, (Dover, 2011)

S19: Unifying Physics of Accelerators, Lasers and Plasma

'Unifying Physics of Accelerators, Lasers and Plasma', A. Seryi, CRC Press 2015**.**

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)

S29: Exploring Solar Systems

"Planetary Sciences", by Imke de Pater and Jack Lissauer
"The solid Earth", C M R Fowler

First Year

Data analysis and Statistics

'Measurements and their Uncertainties A practical guide to modern error analysis', Hughes, Ifan & Hase, Tom, (OUP 2010)
'Scientific Inference: Learning from Data 'SimonVaughan, Cambridge, 2013)

CP1: Physics 1

Classical Mechanics

'Classical Mechanics', M W McCall (Wiley 2001)
'Introduction to Classical Mechanics', A P French & M G Ebison (Chapman & Hall) (Out of print but in most libraries)
'Analytical Mechanics', 6th ed, Fowles & Cassidy (Harcourt 1999)
'Fundamentals of Physics' (Chapters on Mechanics), Halliday, Resnick & Walker (Wiley)
'Physics for Scientists & Engineers', (Chapters on Mechanics) Tipler (W H Freeman 1999)

Special Relativity

'Special Relativity', A P French, (MIT, Physics Series) [Nelson, 1968]
'Spacetime Physics', E F Taylor & J A Wheeler (Freeman, 1992) Several publishers including Nelson, Chapman & Hall.
'Introductory Special Relativity', W G V Rosser
'Lectures on Special Relativity', M G Bowler (Pergamon, 1986)
'Special Theory of Relativity', H Muirhead, (Macmillan)
'Introducing Special Relativity', W S C Williams (Taylor & Francis, 2002)

CP2: Physics 2

Electronics and Circuit Theory

'Electronics Circuits, Amplifiers & Gates', D V Bugg (A Hilger, 1991)**
'Electronics Course Manual', G Peskett (Oxford Physics)
'Basic Electronics for Scientists and Engineers', Dennis L. Eggleston, CUP 2011, ISBN 0521154308 *

Electromagnetism

'Electromagnetism', Second Edition, I S Grant, W R Phillips, (Wiley, 1990) ISBN: 978-0-471-92712-9**
'Electromagnetism, principles and applications', P Lorrain & Dale R Corson, 2nd ed (Freeman) *
'Electricity and Magnetism', W J Duffin, (McGraw Hill)

Optics

'Optics', E Hecht, 4th ed (Addison-Wesley, 2003) *
'Optical Physics', A. Lipson, S. G. Lipson and H. Lipson, 4th ed (Camridge University Press, 2011) *
'Introduction to Modern Optics', G R Fowles, 2nd ed 1975 (still in print as a Dover paperback)
'Essential Principles of Physics', P. M. Whelan and M. J. Hodgson (any edition from the 1970s)
'Essential Principles of Physics', P. M. Whelan and M. J. Hodgson (any edition from the 1970s)

CP3 & CP4: Mathematical Methods 1 & 2

Calculus

'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 *
'All you ever wanted to know about Mathematics but were afraid to ask', L Lyons (CUP, 1995) *

Vectors and Matrices

'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 *

Ordinary Differential Equations and Complex Numbers

'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', M L Boas

Multiple Integrals

'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

Vector Calculus

'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
'Advanced Vector Analysis', C E Weatherburn (1943)

Mathematical Methods

'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 *
'Partial Differential Equations for Scientists and Engineers,' G Stephenson, 3rd ed reprinted 1998, Imperial College Press) **
'Fourier Series and Boundary Value Problems', Churchill and Brown (McGraw-Hill) *
'Intro to Mathematical Physics, Methods & Concepts', Chun wa Wong, (OUP), *
'Mathematical Methods for Physics and Engineering', K F Riley, (CUP), *
'Mathematical Methods of Physics', J Mathews and R L Walker, (Benjamin) *

Second Year

Mathematical Methods

See first year list.
'Mathematical Methods for Physicists', Arfken and Weber (Elsevier)

A1: Thermal Physics

Statistical and Thermal Physics

Textbook based on the Oxford course as taught up to 2011:
'Concepts in Thermal Physics,' S. J. Blundell and K. M. Blundell (2nd edition, OUP 2009) **

More undergraduate textbooks:
'Fundamentals of Statistical and Thermal Physics,' F. Reif (Waveland Press 2008) *
'Equilibrium Thermodynamics,' C. J. Adkins (3rd edition, CUP 1997) *
'Statistical Physics,' F. Mandl (2nd edition, Wiley-Blackwell 2002)
'Elementary Statistical Physics,' C. Kittel (Dover)
'Thermodynamics and the Kinetic Theory of Gases,' W. Pauli (Volume 3 of Pauli Lectures on Physics, Dover 2003) *

More advanced-level books:
'Statistical Thermodynamics,' E. Schroedinger (Dover 1989) * [a beautiful and very concise treatment of the key topics in statistical mechanics, a bravura performance by a great theoretical physicist; may not be an easy undergraduate read, but well worth the effort!]
'Statistical Physics, Part I,' L. D. Landau and E. M. Lifshitz (3rd edition, Volume 5 of the Landau and Lifshitz Course of Theoretical Physics, Butterworth-Heinemann, 2000) ** [the Bible of statistical physics for theoretically inclined minds]
'Physical Kinetics,' E. M. Lifshitz and L. P. Pitaevskii (Volume 10 of the Landau and Lifshitz Course of Theoretical Physics, Butterworth-Heinemann, 1999)
'The Mathematical Theory of Non-uniform Gases: An Account of the Kinetic Theory of Viscosity, Thermal Conduction and Diffusion in Gases,' S. Chapman and T. G. Cowling (CUP 1991) [the Cambridge Bible of kinetic theory, not a page-turner, but VERY thorough]
'Statistical Physics of Particles,' M. Kardar (CUP 2007)

A2: Electromagnetism and Optics

Electromagnetism

'Introduction to Electrodynamics', 3rd ed., David J. Griffiths **
`Electromagnetism', 2nd ed., I.S. Grant and W.R. Phillips
`Fields and Waves in Communication Electronics', 3rd ed., S. Ramo, J.R. Whinnery and T. van Duzer
'Classical Electrodynamics', 3rd ed., J D Jackson
'Electricity & Magnetism', 3rd ed., B I Bleaney & B Bleaney
'Electromagnetic Fields and Waves', P. Lorrain, D.R. Corson and F. Lorrain

Optics

"Optics", E Hecht, 4th ed (Addison-Wesley, 2002) **
"Optical Physics" 4th Edition Ariel Lipson, Stephen G. Lipson, Henry Lipson (Cambridge University Press 2010)*
"Modern Classical Optics", G.A. Brooker, Oxford Masters Series (Oxford University Press, 2003)
"Principles of Optics", M Born and E Wolf , 7th ed (Pergamon, 1999)

A3: Quantum Physics

Quantum Physics
"The Physics of Quantum Mechanics" J Binney and D Skinner, (Cappella Archive http://www.cappella.demon.co.uk/cappubs.html#natsci) ISBN 978-1-902918-51-8; **available at Clarendon reception of £20.00** Written for the course**
'The Feynman Lectures on Physics Vol. 3', R. Feynman, Leighton & Sands A classic but unorthodox QM text. Full of deep physical insight*
'The 'Strange World of Quantum Mechanics', D. Styer (CUP paperback) A non-technical introduction that may help bring history & ideas into focus*
The Principles of Quantum Mechanics (International Series of Monographs on Physics) <http://www.amazon.com/Principles-Quantum-Mechanics-International-Monographs/dp/0198520115/ref=sr_1_1?ie=UTF8&s=books&qid=1276775894&sr=1-1> by P. A. M. Dirac <http://www.amazon.com/P.-A.-M.-Dirac/e/B000API1UQ/ref=sr_ntt_srch_lnk_1?_encoding=UTF8&qid=1276775894&sr=1-1>
(OUP paperback) A very beautiful book for those who appreciate mathematical elegance and clarity.*
A Z Capri, Non-relativistic Quantum Mechanics, World Scientific, 3rd ed. 2002 * Contains an accessible discussion of mathematical issues not normally discussed in QM texts
C Cohen-Tannoudji, B Diu and F Laloë, Quantum Mechanics (2 vols) Wiley-VCH 1977 *. A brilliant example of the more formal French style of physics textbook.
B H Bransden and C J Joachain, Physics of Atoms and Molecules, Prentice Hall 2002 *. Contains useful material on quantum mechanics of helium.
"Principles of Quantum Mechanics", 2nd ed, R. Shankar (Plenum Press)

Third Year

B1: Flows, Fluctuations and Complexity

Physical Fluid Dynamics, D. J. Tritton (CUP, 2nd edition, 1988), ISBN- 10: 0198544936**
Elementary Fluid Dynamics, D. J. Acheson (OUP, 1990), ISBN-10: 019859679*
Fluid Dynamics for Physicists, F E Faber, (CUP, 1995), ISBN-10: 0521429692*
Nonlinear Dynamics and Chaos, S. H. Strogatz (Perseus, 1994), ISBN 0738204536**
'Physical Biology of the Cell', R. Phillips, J. Kondev & J. Theriot (Garland Science, 2008) **
'Biological Physics: Energy, Information, Life', updated 1st edition, Philip Nelson (W.H.Freeman & Co Ltd, 2008)**
'Physical Biology of the Cel'l, R. Phillips, J. Kondev & J. Theriot (Garland Science, 2008) **
'Biological Physics: Energy, Information, Life', updated 1st edition, Philip Nelson (W.H.Freeman & Co Ltd, 2008)**
'Molecular and Cellular Biophysics', M. B. Jackson (CUP, 2006) **
'Biochemistry' 3rd Ed, D. Voet & J.G. Voet, (John Wiley & Sons Inc, 2005) OR
'Biochemistry', 6th Ed., L. Stryer, et al (W.H.Freeman & Co Ltd, 2006)
'Mechanics of Motor Proteins and the Cytoskeleton', J. Howard, Sinauer Associates Inc. (ISBN) 0-87893-333-6).

B2: Symmetry and Relativity

Special Relativity

'Six not-so-easy pieces : Einstein's relativity, symmetry and space-time', R P Feynmann (Allen Lane, 1998)
'Introduction to Special Relativity', W Rindler, (OUP) **
'Einstein's miraculous year', J Stachel (Princeton, 1998)
'The Special Theory of Relativity', Muirhead (Macmillan)
'An Introduction to Special Relativity and its applications', F N H Robinson, (World Scientific)**
'Introducing Special Relativity', W S C Williams (Taylor & Francis, 2002) ISBN: 9780415277624
"Relativity made relatively easy", A. Steane (OUP)**

B3: Quantum, Atomic and Molecular Physics

'Atomic Physics', Chris Foot (Oxford Master Series in Physics) **
'Atomic & Quantum Physics', Haken & Wolf (Springer)
'Principles of Modern Physics', RB Leighton (McGraw Hill) *
'Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles', E Eisberg and R Resnick (Wiley)*
'Elementary Atomic Structure', G K Woodgate (Oxford) *
'Atomic Physics', J C Willmott (Wiley) Manchester Physics Series
Laser Physics, S Hooker and C Webb (Oxford Master Series in Physics)**
"The Physics of Quantum Mechanics" J Binney and D Skinner, (Cappella Archive http://www.cappella.demon.co.uk/cappubs.html#natsci) *
'Principles of Lasers,' Orazio Svelto, (Plenum Publishing Corporation KLUWER ACADEMIC PUBL)
ISBN10: 0306457482, ISBN13: 9780306457487
"Laser Physics" Hooker and Webb, ISBN13: 9780198506911, ISBN10: 0198506910

B4: Sub-atomic Physics

'Nuclear and Particle Physics: An Introduction', Brian R. Martin (Wiley, 2006) ISBN: 978-0-470-02532-1 **
'Introduction to Nuclear Physics', W N Cottingham & D A Greenwood, 2nd edition, (CUP, 2001) *
'Particle Physics', A Martin & G Shaw, (Wiley) *
'Modern quantum mechanics', Jun John Sakurai, San Fu Tuan, 2nd edition, Addison-Wesley Pub. Co., 1994
ISBN 0201539292, 9780201539295
'Nuclear and Particle Physics', W S C Williams, (OUP, 1997)
'Introduction to Nuclear and Particle Physics', A Das & T Ferbel, (Wiley)
'Introductory Nuclear Physics', P.E. Hodgson, E Gadioli and E Gadioli Erba, Oxford Science Publications, ISBN 0 19 851897 8 (paperback)

B5: General Relativity and Cosmology

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

B6: Condensed-Matter Physics

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

Fourth year

C1: Astrophysics

'Introductory Astronomy and Astrophysics', Zeilik and Gregory (Saunders) *
'An Introduction to Modern Astronomy', B. Carroll and DA Ostlie (Addison-Wesley)
'Astrophysics I, II', Bowers and Deeming (Jones and Bartlett)
'Galactic Astronomy', Binney and Merrifield (Freeman)
'High Energy Astrophysics I, II', Longair (CUP)
'Galactic Dynamics', J Binney & S Tremaine (Princeton University, 1987)
'Physics & Chemistry of the Interstellar Medium', Sun Kwok (University Science Books, Sausalito, California) ISBN-10: I-891389-46-7

C2: Laser Science and Quantum Information Processing

Quantum Information

'Quantum Information, Computation and Communication', J. A. Jones and D. Jaksch (CUP i, 2012)**
'Quantum Computing: A Short Course from Theory to Experiment', J. Stolze and D. Suter 2nd Ed. (Wiley 2008) *
'Quantum Computer Science', N. D. Mermin (CUP 2007)
'Feynman Lectures on Computation', Richard P. Feynman, Anthony J. G. Hey, Robin W. Allen (Penguin 1999)

Laser Science and Modern Optics

'Lasers and Electro-Optics: Fundamentals and Engineering', C. C. Davies (CUP 1996)**
'Laser Physics' S. Hooker and C. Webb (OUP 2010)*
'Modern Classical Optics', G. Brooker (OUP 2003)*
'Laser Electronics', J. T. Verdeyen, (Prentice-Hall, 3rd ed. 1995)
'Quantum Electronics', A. Yariv, (Wiley, 3rd ed. 1989)
'Optical Electronics in Modern Communications', A. Yariv (OUP 1997)
'Fundamentals of Photonics', B. E. A. Saleh & M. C. Tech (Wiley 1991)
'Principles of Lasers,' O. Svelto (Springer 2010)

Quantum Optics

'Modern Foundations of Quantum Optics', V. Vedral (Imperial College Press 2001)**

C3: Condensed Matter Physics

General texts

'Solid State Physics', N W Ashcroft and N D Mermin (Saunders, 1976) **
'Solid State Physics', G Burns (Academic Press, 1990) *
'Introduction to Solid State Physics', C Kittel (John Wiley & Sons, 8th ed., 2005) *
'Principles of Condensed Matter Physics', P M Chaikin and T C Lubensky (CUP, 2000) *

Individual topics

● *Structure & Dynamics*
'Structure and Dynamics', M T Dove (OUP, 2003) **
'The Basics of Crystallography and Diffraction', C Hammond (OUP, 2001) *
'Fundamentals of Crystallography', C Giacovazzo, H L Monaco, G Artioli, D Viterbo, G Ferraris, G Gilli, G Zanotti and M Catti (OUP, 2002) *
● *Electronic Properties*
'Band Theory and Electronic Properties of Solids', J Singleton (OUP, 2001) **
● *Optical Properties*
'Optical Properties of Solids', A M Fox (OUP, 2001) **
● *Magnetism*
'Magnetism in Condensed Matter', S J Blundell (OUP, 2000) **
'Theory of Magnetism', K Yosida (Springer, 1996) *
● *Superconductivity*
'Superconductivity, Superfluids and Condensates', J F Annett, (OUP, 2004) **
'Introduction to Superconductivity', M Tinkham, (McGraw-Hill, 1996) *
'Superconductivity: A Very Short Introduction', S J Blundell (OUP, 2009) *

C4: Particle Physics

Introductory

'Particle Physics', B R Martin & G P Shaw (Wiley (3rd Ed))
Course Texts (There is no text that matches the scope and level of the course very well)
'Introduction to Elementary Particle Physics', A Bettini (CUP) *
'Nuclear and Particle Physics', W E Burcham & M Jobes (Longman) *
'Introduction to High Energy Physics', D H Perkins (CUP (4th ed)) *
'Introduction to Elementary Particles', M Griffiths (Wiley (2nd Ed))
'Femtophysics', M G Bowler (Pergamon)

Reference (Most are graduate level texts)
'Experimental foundations of Particle Physics', R Cahn & G Goldhaber (CUP (2nd Ed))
'An Intro. to the Standard Model of Part. Phys.', Cottingham & Greenwood (CUP (2nd Ed))
'Quarks & Leptons', F Halzen & A D Martin (Wiley)
'Deep Inelastic Scattering', Devenish & Cooper-Sarkar (OUP)
'Particle Astrophysics', D H Perkins (OUP (2nd Ed))

RQM

'Relativistic Quantum Mechanics', P Strange (CUP)
'Relativistic Quantum Mechanics', I J R Aitchison (Macmillan)
'Quantum Mechanics II', R H Landau (Wiley)

Accelerators & Detectors

'The Physics of Particle Accelerators', K Wille (OUP)
'An introduction to Particle Accelerators', E J N Wilson (Clarendon Press)
'Detectors for Particle Radiation', K Kleinknecht (CUP (2nd Ed))
'Particle Detectors', C Grupen (CUP)

C5: Physics of Atmospheres and Oceans

General Course Texts (There is no text that matches the scope and level of the course very well)

'Fluid Dynamics of the Mid-Latitude Atmosphere', BJ Hoskins and I James (Wiley-Blackwell 2014), ISBN-10: 0470795190 'An Introduction to Atmospheric Physics' (2nd edition), D. G. Andrews (CUP, 2010), ISBN-13: 9780521693189
'The Physics of Atmospheres', 3rd edition, J. T. Houghton (CUP, 2002), ISBN-10: 0521011221
'Atmospheric Science, An Introductory Survey', 2nd edition, J. M. Wallace and P. V. Hobbs (AP, 2006), ISBN-10: 012732951X

Reference for individual topics:

Aerosols, Clouds and Chemistry
'Atmospheric Chemistry and Physics: From Air Pollution to Climate Change', 2nd edition, J. H. Seinfeld and S. N. Pandis (Wiley-Interscience, 2006), ISBN-10: 0471720186
'The Chemistry & Physics of Stratospheric Ozone', A. Dessler (AP, 2000), ISBN-10: 0122120515
'A Short Course in Cloud Physics', 3rd edition, R. R. Rogers and M. K. Yau (Butterworth-Heinemann, 1984), ISBN-10: 0750632151
'Chemistry of Atmospheres', 3rd edition, R. P. Wayne (OUP, 2000), ISBN-10: 019850375X

Inverse Methods and Predictability
'Inverse Methods for Atmospheric Sounding: Theory and Practice', C. D. Rodgers (World Scientific Publishing, 2000), ISBN-10: 981022740X
'Discrete Inverse and State Estimation Problems: With Geophysical Fluid Applications', E. C. Wunsch (CUP, 2012), ISBN-10: 1107406064
'Atmospheric Modeling, Data Assimilation and Predictability', E. Kalnay (CUP, 2002), ISBN-10: 0521796296

Radiation
'Atmospheric Radiation', R. L. Goody and Y. L. Yung (OUP, 1995), ISBN-10: 0195102916
'An Introduction to Atmospheric Radiation', 2nd edition, K. N. Liou (AP, 2002), ISBN-10: 0124514510
'A First Course in Atmospheric Radiation', 2nd edition, G. W. Petty (Sundog Publishing, 2006), ISBN-10: 0972903313
'Remote Sensing of the Lower Atmosphere', G. L. Stephens (OUP, 1994), ISBN-10: 0195081889

Geophysical Fluid Dynamics
'Atmospheric and Oceanic Fluid Dynamics', G. Vallis (CUP, 2006), ISBN-10: 0521849691
'An Introduction to Dynamic Meteorology', 4th edition, J. R. Holton (AP, 2000), ISBN-10: 0123540151

Planetary Atmospheres:
'Giant Planets of our Solar System', P. G. J. Irwin (Springer-Praxis, 2003), ISBN-10: 3540006818
'The Martian Climate Revisited', P. L. Read and S. R. Lewis (Springer-Praxis, 2004), ISBN-10: 354040743X

C6: Theoretical Physics

'Introduction to Gauge Field Theory', D. Bailin and A. Love, mainly chapters 1 – 6 **
'Statistical Mechanics', R. P. Feynman mainly chapters 3, 4 and 6 **
'Statistical and Thermal Physics', F. Reif, chapter 15 **
'Statistical Mechanics of Phase Transitions', J. M. Yeomans, chapters 1 – 5 **
An overview A. Zee, 'Quantum Field Theory in a Nutshell', Part I **
'A Modern Course in Statistical Physics', L. E. Reichl (McGraw-Hill) *
'Stochastic Processes in Physics and Chemistry', N. G. van Kampen (North Holland) *
'Introduction to Statistical Mechanics', K. Huang (CRC Press) *
'An Introduction to Quantum Field Theory', M. V. Peskin and D. V. Schroeder (Addison-Wesley) *
'Principles of Condensed Matter Physics', P. M. Chaiken and T. C. Lubensky (CUP) *

C7: Biological Physics

'Biological Physics: Energy, Information, Life', Philip Nelson (W.H.Freeman & Co Ltd)
'Molecular Biology of the Cell', Bruce Alberts (Editor),(Garland Science)
'Biochemistry', Donald Voet, (John Wiley & Sons Inc) OR
'Biochemistry', 5th Ed., Lubert Stryer, et al (W.H.Freeman & Co Ltd)
'Random Walks in Biology', Howard C. Berg (Princeton University Press)
'Mechanics of Motor Proteins and the Cytoskeleton' Jonathon Howard (Palgrave Macmillan)
'An Introduction to Systems Biology: Design Principles of Biological circuits', U. Alon, Chapman and Hall (2006) *

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').

The exact requirements in a given year will be published by the Examiners. For some Prelims papers in Maths calculators are not allowed at all.

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

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

Preliminary Examination in Physics

Each of the Papers CP1 - CP4 is a 2½ hour paper in two sections
Section A: Short compulsory questions (total marks 40)
Section B: Answer 3 problems from 4 (total marks 60)

Syllabuses for CP1 CP2, CP3 and CP4.
also **Preliminary Examination in Physics and Philosophy**
Syllabuses for CP1, CP3, CP4
Part A Physics and Philosophy A2P (CP2 without Circuit Theory and Optics)

CP1: Physics 1

Newton's law of motion. Mechanics of particles in one dimension. Energy, work and impulse. Conservation of linear momentum including problems where the mass changes, e.g. the motion of a rocket ejecting fuel. Conservation of energy.

Vector formulation of Newton's law of motion. Time-dependent vectors and differentiation of vectors.

Mechanics of particles in two dimensions. Equations of motion in Cartesian and plane polar co-ordinates. Simple cases of the motion of charged particles in uniform **E** and **B** fields.

Projectiles moving under gravity, including such motion subject to a damping force proportional to velocity. Dimensional Analysis.

Systems of point particles. Centre of mass (or momentum) frame and its uses. Torque and angular momentum. Conservation of angular momentum. Two-body collisions.

Central forces. Importance of conservation of energy and angular momentum. Classification of orbits as bound or unbound (derivation of equation for u=1/r not required; explicit treatment of hyperbolae and ellipses not required). Inverse square central forces. Examples from planetary and satellite motion and motion of charged particles under the Coulomb force. Distance of closest approach and angle of deviation.

Calculus of variations. Principle of stationary action (Hamilton principle). The Euler-Lagrange equation. Constraints. Application to particle motion in one and two dimensions. Small oscillations, normal coordinates. Compound pendulum. Conservation laws. Noether's theorem. The Hamiltonian and energy conservation.

Moment of inertia of a system of particles. Use of perpendicular- and parallel-axis theorems. Moment of inertia of simple bodies. Simple problems of rigid body dynamics. Angular impulse, collision and rolling. The concept of principal axes. Angular momentum and total energy in rigid body rotation.

Special Relativity

Special theory of relativity restricted throughout to problems in one or two space dimensions. The constancy of the speed of light; simultaneity. The Lorentz transformation (derivation not required). Time dilation and length contraction. The addition of velocities. Invariance of the space-time interval. Proper time.

Energy, momentum, rest mass and their relationship for a single particle. Conservation of energy and momentum and the use of invariants in the formation sub-atomic particles. Elementary kinematics of the scattering and decay of sub-atomic particles, including photon scattering. Relativistic Doppler effect (longitudinal only).

CP2: Physics 2

The treatment of electromagnetism is restricted to fields in vacuo. Vector operator identities required will be given on the data sheet and complicated manipulations of vector operators will not be set.

Electromagnetism

Coulomb's law. The electric field **E** and potential due to a point charge and systems of point charges, including the electric dipole. The couple and force on, and the energy of, a dipole in an external electric field. Energy of a system of point charges; energy stored in an electric field. Gauss' Law; the **E** field and potential due to surface and volume distributions of charge (including simple examples of the method of images), no field inside a closed conductor. Force on a conductor. The capacitance of parallel-plate, cylindrical and spherical capacitors, energy stored in capacitors.

The forces between wires carrying steady currents. The magnetic field B, Ampere's law, Gauss' Law ("no magnetic monopoles"), the Biot-Savart Law. The **B** field due to currents in a long straight wire, in a circular loop (on axis only) and in straight and toroidal solenoids. The magnetic dipole; its **B** field. The force and couple on, and the energy of, a dipole in an external **B** field. Energy stored in a **B** field.

The force on a charged particle in **E** and **B** fields.

Electromagnetic induction, the laws of Faraday and Lenz. EMFs generated by an external, changing magnetic field threading a circuit and due to the motion of a circuit in an external magnetic field, the flux rule. Self and mutual inductance: calculation for simple circuits, energy stored in inductors. The transformer.

Charge conservation, Ampere's law applied to a charging capacitor, Maxwell's addition to Ampere's law ("displacement current").

Maxwell's equations for fields in a vacuum (rectangular coordinates only). Plane electromagnetic waves in empty space: their speed; the relationships between **E**, **B** and the direction of propagation.

Circuit Theory

EMF and voltage drop. Resistance, capacitance, inductance and their symbolic representation. Growth and decay of currents in circuits, time constant. The concept of complex impedance in steady-state AC circuit analysis.

Ideal Op-amp: inverting and non inverting amplifier circuits; summation, integration and differentiation circuits.

Optics

Elementary geometrical optics in the paraxial approximation. Refractive index; reflection and refraction at a plane boundary from Huygens' principle and Fermat's principle; Snell's Law; total internal reflection. Image formation by reflection at a spherical boundary; concave and convex mirrors. Real and virtual images. Magnification. Image formation by refraction at a spherical boundary and by converging and diverging thin lenses. Derivation of the expression for the focal length of a thin lens. *[Non-examinable: Image formation by systems of thin lenses or mirrors as illustrated by: a simple astronomical telescope consisting of two convex lenses, a simple reflecting telescope, a simple microscope.]*

Simple two-slit interference (restricted to slits of negligible width). The diffraction grating, its experimental arrangement; conditions for proper illumination. The dispersion of a diffraction grating. (The multiple-slit interference pattern and the resolution of a diffraction grating are excluded.) Fraunhofer diffraction by a single slit. The resolution of a simple lens.

Note: the above electromagnetism syllabus is also that for the Physics and Philosophy Part A paper A2P (Electromagnetism), excluding the sections on Circuit Theory and Optics.

CP3: Mathematical Methods 1

Differential equations and complex numbers

Complex numbers, definitions and operations. The Argand diagram; modulus and argument (phase) and their geometric interpretation; curves in the Argand diagram. De Moivre's theorem. Elementary functions (polynomial, trigonometric, exponential, hyperbolic, logarithmic) of a complex variable. (Complex transformations and complex differentiation and integration are excluded.)

Ordinary differential equations; integrating factors. Second-order linear differential equations with constant coefficients; complementary functions and particular integrals. Application to forced vibrations of mechanical or electrical resonant systems, including the use of a complex displacement variable; critical damping; quality factor (Q), bandwidth, rms, peak and average values. *[Physical interpretation of complex impedance and power factor is not assumed]*

Vector algebra

Addition of vectors, multiplication by a scalar. Basis vectors and components. Magnitude of a vector. Scalar product. Vector product. Triple product. Equations of lines, planes, spheres. Using vectors to find distances.

Matrices

Basic matrix algebra: addition, multiplication, functions of matrices. Transpose and Hermitian conjugate of a matrix. Trace, determinant, inverse and rank of a matrix. Orthogonal, Hermitian and unitary matrices. Vector spaces in generality. Basis vectors. Scalar product. Dual vectors. Linear operators and relation to matrices. Simultaneous linear equations and their solutions. Determination of eigenvalues and eigenvectors, characteristic polynomial. Properties of eigenvalues and eigenvectors of Hermitian linear operators. Matrix diagonalisation.

CP4: Mathematical Methods 2

Elementary ideas of sequences, series, limits and convergence. (Questions on determining the convergence or otherwise of a series will not be set.) Taylor and MacLaurin series and their application to the local approximation of a function of one variable by a polynomial, and to finding limits. (Knowledge of and use of the exact form of the remainder are excluded.) Differentiation of functions of one variable including function of a function and implicit differentiation. Changing variables in a differential equation, integration of functions of one variable including the methods of integration by parts and by change of variable, though only simple uses of these techniques will be required, such as $\int x\sin x\, dx$ and $\int x\exp(-x^2)\, dx$. The relation between integration and differentiation, i.e. $\int_a^b dx\,(df/dx)$ and $d/dx(\int_a^x f(x')\,dx')$.

Differential calculus of functions of more than one variable. Functions of two variables as surfaces. Partial differentiation, chain rule and differentials and their use to evaluate small changes. Simple transformations of first order coefficients. (Questions on transformations of higher order coefficients are excluded.) Taylor expansion for two variables, maxima, minima and saddle points of functions of two variables.

Double integrals and their evaluation by repeated integration in Cartesian, plane polar and other specified coordinate systems. Jacobians. Line, surface and volume integrals, evaluation by change of variables (Cartesian, plane polar, spherical polar coordinates and cylindrical coordinates only unless the transformation to be used is specified). Integrals around closed curves and exact differentials. Scalar and vector fields. The operations of grad, div and curl and understanding and use of identities involving these. The statements of the theorems of Gauss and Stokes with simple applications. Conservative fields.

Waves

Coupled undamped oscillations in systems with two degrees of freedom. Normal frequencies, and amplitude ratios in normal modes. General solution (for two coupled oscillators) as a superposition of modes. Total energy, and individual mode energies. Response to a sinusoidal driving term.

Derivation of the one-dimensional wave equation and its application to transverse waves on a stretched string. D'Alembert's solution. Sinusoidal solutions and their complex representation. Characteristics of wave motion in one dimension: amplitude, phase, frequency, wavelength, wavenumber, phase velocity. Energy in a vibrating string. Travelling waves: energy, power, impedance, reflection and transmission at a boundary. Superposition of two waves of different frequencies: beats and elementary discussion of construction of wave packets; qualitative discussion of dispersive media; group velocity. Method of separation of variables for the one-dimensional wave equation; separation constants. Modes of a string with fixed end points (standing waves): superposition of modes, energy as a sum of mode energies.

Final Honour School - Part A

A knowledge of the topics in the syllabuses for the four compulsory physics Prelims papers will be assumed. Emphasis will be placed on testing a candidate's conceptual and experimental understanding of the subjects, apart from explicitly mathematical questions.

Non-examinable topics. Material under this heading will be covered in the lectures (with associated problems). Questions on these topics will not be set in Part A, but general knowledge of the material will be assumed by the 3rd year lectures. Only if these topics appear in the Part B syllabus may explicit questions be set on them in that examination.

Each of the three A Papers is a 3-hour paper in two sections
Section A: Short compulsory questions (total marks 40)
Section B: Answer 3 problems from 4 (total marks 60)

Mathematical Methods

Matrices and linear transformations, including translations and rotations in three dimensions and Lorentz transformations in four dimensions. Eigenvalues and eigenvectors of real symmetric matrices and of Hermitian matrices. Diagonalization of real symmetric matrices; diagonalization of Hermitian matrices. The method of separation of variables in linear partial differential equations in two, three and four variables; and for problems with spherical and planar symmetry. Use of Cartesian, spherical polar and cylindrical polar coordinates (proofs of the form of D^2will not be required). Eigenvalues and eigenfunctions of second-order linear ordinary differential equations of the Sturm–Liouville type; orthogonality of eigenfunctions belonging to different eigenvalues; simple eigenfunction expansions including Fourier series. Fourier transform, its inverse, and the convolution theorem. Concept and use of the delta function. Solution by separation of variables for problems with spherical and planar symmetry. Steady-state problems, initial-value problems.

Probability and Statistics

Essential properties and applicability of basic probability distributions (Binomial, Poisson, Normal, Chi-squared); Appropriate application of "Trial penalties" in the case of multiple, independent tests. Simple applications of Bayes' Theorem. Basic error propagation. *[Non-examinable: Assessment of data/model consistency via probability distributions; maximum likelihood.]*

The above material on mathematical methods, probability and statistics is not attributed to a specific paper.

Short questions on mathematical methods, probability and statistics will be set in one or more of papers A1, A2 and A3. It is expected that the total credit for these short questions will amount to about 15% of the total credit for short questions, as this is roughly the length of the mathematical methods course as a fraction of all courses for papers A1, A2 and A3. One long question on mathematical methods may be set in one of papers A1, A2 or A3.

A1: Thermal Physics

Kinetic Theory

Maxwell distribution of velocities: derivation assuming the Boltzmann factor, calculation of averages, experimental verification. Derivation of pressure and effusion formulae, distribution of velocities in an effusing beam, simple kinetic theory expressions for mean free path, thermal conductivity and viscosity; dependence on temperature and pressure, limits of validity. Practical applications of kinetic theory.

Heat transport

Conduction, radiation and convection as heat-transport mechanisms. The approximation that heat flux is proportional to the temperature gradient. Derivation of the heat diffusion equation. Generalization to systems in which heat is generated at a steady rate per unit volume. Problems involving sinusoidally varying surface temperatures.

Thermodynamics

Zeroth & first laws. Heat, work and internal energy: the concept of a function of state. Slow changes and the connection with statistical mechanics: entropy and pressure as functions of state. Heat engines: Kelvin's statement of the second law of thermodynamics and the equivalence and superiority of reversible engines. The significance of $\int dQ/T=0$ and the fact that entropy is a function of state. Practical realization of the thermodynamic temperature scale. Entropy as dQ (reversible)/T. Enthalpy, Helmholtz energy and Gibbs energy as functions of state. Maxwell relations. Concept of the equation of state; thermodynamic implications. Ideal gas, van der Waals gas. Reversible and free expansion of gas; changes in internal energy and entropy in ideal and non-ideal cases. Joule–Kelvin expansion; inversion temperature and microscopic reason for cooling. Impossibility of global entropy decreasing: connection to latent heat in phase changes. *[Non-examinable: Constancy of global entropy during fluctuations around equilibrium.]* Chemical potential and its relation to Gibbs energy. Equality of chemical potential between phases in equilibrium. Latent heat and the concepts of first-order and continuous phase changes. Clausius–Clapeyron equation and simple applications. Simple practical examples of the use of thermodynamics.

Statistical mechanics

Boltzmann factor. Partition function and its relation to internal energy, entropy, Helmholtz energy, heat capacities and equations of state. *[Non-examinable: Quantum states and the Gibbs hypothesis.]* Density of states; application to: the spin-half paramagnet; simple harmonic oscillator (Einstein model of a solid); perfect gas; vibrational excitations of a diatomic gas; rotational excitations of a heteronuclear diatomic gas. Equipartition of energy. Bosons and fermions: Fermi–Dirac and Bose–Einstein distribution functions for non-interacting, indistinguishable particles. Simple treatment of the partition function for bosons and fermions when the particle number is not restricted and when it is: microcanonical, canonical and grand canonical ensemble. Chemical potential. High-temperature limit and the Maxwell–Boltzmann distribution. *[Non-examinable: Simple treatment of fluctuations.]* Low-temperature limit for fermions: Fermi energy and low-temperature limit of the heat capacity; application to electrons in metals and degenerate stars. Low-temperature limit for boson gas: Bose–Einstein condensation: calculation of the critical temperature of the phase transition; heat capacity; relevance to superfluidity in helium. The photon gas: Planck distribution, Stefan–Boltzmann law. *[Non-examinable: Kirchhoff's law.]*

A2: Electromagnetism and Optics

Electromagnetism

Electromagnetic waves in free space. Derivation of expressions for the energy density and energy flux (Poynting vector) in an electromagnetic field. Radiation pressure.

Magnetic vector potential. The change of **E** and **B** fields under Lorentz transformations in simple cases. Simple description of radiation fields from an electric dipole.

Dielectric media, polarisation density and the electric displacement **D**. Dielectric permittivity and susceptibility. Boundary conditions on **E** and **D** at an interface between two dielectrics. Magnetic media, magnetisation density and the magnetic field strength H. Magnetic permeability and susceptibility; properties of magnetic materials as represented by hysteresis curves. Boundary conditions on **B** and **H** at an interface between two magnetic media. Maxwell's equations in the presence of dielectric and magnetic media.

Electromagnetic wave equation in dielectrics: refractive index and impedance of the medium. Reflection and transmission of light at a plane interface between two dielectric media. The electromagnetic wave equation in a conductor: skin depth. Electromagnetic waves in a plasma; the plasma frequency. Scattering, dispersion and absorption of electromagnetic waves, treated in terms of the response of a damped classical harmonic oscillator.

Treatment of electrostatic problems by solution of Poisson's equation using separation of variables in Cartesian, cylindrical or spherical coordinate systems.

Theory of a loss-free transmission line: characteristic impedance and wave speed. Reflection and transmission of signals at connections between transmission lines and at loads; impedance matching using a quarter-wavelength transmission line.

[Non-examinable: Rectangular loss-less waveguides and resonators.]

Optics

Diffraction, and interference by division of wave front (quasi-monochromatic light). Questions on diffraction will be limited to the Fraunhofer case. Statement of the Fraunhofer condition. Practical importance of Fraunhofer diffraction and experimental arrangements for its observation. Derivation of patterns for multiple slits and the rectangular aperture using Huygens-Fresnel theory with a scalar amplitude and neglecting obliquity factors. (The assumptions involved in this theory will not be asked for.) The resolving power of a telescope. Fourier transforms in Fraunhofer diffraction: the decomposition of a screen transmission function with simple periodic structure into its spatial frequency components. Spatial filtering. *[Non-examinable: The Gaussian function and apodization.]* The resolving power of a microscope with coherent illumination.

Interference by division of amplitude (quasi-monochromatic light). Two-beam interference, restricted to the limiting cases of fringes of equal thickness and of equal inclination. Importance in modern optical and photonic devices as illustrated by: the Michelson interferometer (including its use as a Fourier-transform spectrometer); the Fabry–Perot etalon (derivation of the pattern, definition of finesse). Single and multiple $\lambda/4$ coatings for normally incident light: high-reflectors and anti-reflection coatings.

Distinction between completely polarized, partially polarized and unpolarized light. Brewster angle. Total internal reflection . *[Non-examinable: Fresnel equations]*, Phenomenological understanding of birefringence; principles of the use of uniaxial crystals in practical polarizers and wave plates (detailed knowledge of individual devices will not be required). Production and analysis of completely polarized light. Practical applications of polarized light. The interference of polarized light; conditions for observation.

[Non-examinable: Properties of laser radiation; brightness compared to conventional sources; coherence length measured using the Michelson Interferometer. Measurement and use of transverse coherence. Propagation of laser light in optical fibres.]

A3: Quantum Physics

Probabilities and probability amplitudes. Interference, state vectors and the bra-ket notation, wavefunctions. Hermitian operators and physical observables, eigenvalues and expectation values. The effect of measurement on a state; collapse of the wave function. Successive measurements and the uncertainty relations. The relation between simultaneous observables, commutators and complete sets of states.

The time-dependent Schroedinger equation. Energy eigenstates and the time-independent Schroedinger equation. The time evolution of a system not in an energy eigenstate. Wave packets in position and momentum space.

Probability current density.

Wave function of a free particle and its relation to de Broglie's hypothesis and Planck's relation. Particle in one-dimensional square-well potentials of finite and infinite depth. Scattering off, and tunnelling through, a one-dimensional square potential barrier. Circumstances in which a change in potential can be idealised as steep; *[Non examinable: Use of the WKB approximation.]*

The simple harmonic oscillator in one dimension by operator methods. Derivation of energy eigenvalues and eigenfunctions and explicit forms of the eigenfunctions for n=0,1 states.

Amplitudes and wave functions for a system of two particles. Simple examples of entanglement.

Commutation rules for angular momentum operators including raising and lowering operators, their eigenvalues (general derivation of the eigenvalues of L^2 and L_z not required), and explicit form of the spherical harmonics for l=0,1 states. Rotational spectra of simple diatomic molecules.

Representation of spin-1/2 operators by Pauli matrices. The magnetic moment of the electron and precession in a homogeneous magnetic field. The Stern–Gerlach experiment. The combination of two spin-1/2 states into S=0,1; *[non-examinable: Derivation of states of well-defined total angular momentum using raising and lowering operators]*. Rules for combining angular momenta in general (derivation not required). *[Non-examinable: Spectroscopic notation.]*

Hamiltonian for the gross structure of the hydrogen atom. Centre of mass motion and reduced particle. Separation of the kinetic-energy operator into radial and angular parts. Derivation of the allowed energies; principal and orbital angular-momentum quantum numbers; degeneracy of energy levels.

Functional forms and physical interpretation of the wavefunctions for n<3.

First-order time-independent perturbation theory, both non-degenerate and degenerate (questions will be restricted to systems where the solution of the characteristic equation can be obtained by elementary means). Interaction of a hydrogen atom with a strong uniform external magnetic field. The linear and quadratic Stark effects in hydrogen.

Exchange symmetry for systems with identical fermions or bosons; derivation of the Pauli principle. Gross-structure Hamiltonian of helium. Implications of exchange symmetry for wavefunctions of stationary states of helium; singlet and triplet states. Estimation of the energies of the lowest few states using hydrogenic wavefunctions and perturbation theory.

The variational method for ground-state energies; application to helium.

The adiabatic and sudden approximations with simple applications.

Time-dependent perturbation theory. The interaction of a hydrogen atom with an oscillating external electric field; dipole matrix elements, selection rules and the connection to angular-momentum conservation. Transition to a continuum; density of states, Fermi's golden rule.

[Non-examinable -Classical uncertainty in quantum mechanics: pure and impure states. The density matrix and trace rules. Time-evolution of the density matrix. Measurement and loss of coherence.]

Final Honour School - Part B

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

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

B1: Flows, fluctuations and complexity

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

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

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

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

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

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

B2: Symmetry & relativity

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

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

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

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

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

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

B3: Quantum, atomic and molecular physics

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

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

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

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

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

B4: Sub-atomic Physics

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

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

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

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

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

B5: General relativity and cosmology

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

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

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

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

Experimental tests of General Relativity: precession of perihelion of Mercury; binary pulsar.

Homogeneous isotropic spacetimes, Friedmann equations, redshift, scale factor, luminosity distance.

The expanding universe: its contents and energy-momentum tensor. Closed and open universes. Cosmological distance ladder; Hubble constant; deceleration and acceleration; observational evidence for acceleration from high-z supernovae.

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

B6: Condensed-matter physics

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

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

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

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

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

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

Magnetic susceptibility, diamagnetism (descriptive treatment only), application of Hund's rules to determination of magnetic ground states of isolated ions, paramagnetism of isolated atoms/ions (temperature dependence of magnetization, Curie's law), Pauli paramagnetism. Magnetic ordering . Weiss molecular field theory of ferromagnetism, Curie temperature, Curie–Weiss susceptibility, exchange interactions. Ferromagnetic domains, domain (Bloch) walls. *[Non-examinable: Systems with $J > ½$, antiferromagnetism, ferrimagnetism, itinerant ferromagnetism, Hubbard model].*

Syllabuses for Short Options

*Short Options will be examined by a single compendium paper divided into sections - one for each option - each containing 3 questions. Candidates offering **one** Short Option should attempt two questions from **one section** in 1½ hours. Candidates offering **two** Short Options should attempt **two questions** from each of two sections in 3 hours. All questions are worth 25 marks. For restrictions and other administrative details, refer to page 27.*

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.

S02: Astrophysics: from planets to the cosmos

The limitations of astrophysics. The scale of the Universe. Motions of the Solar System bodies, Keplers laws. Detection and properties of exo-planets. The Sun as a star. Space weather. Physical properties of stars. Stellar structure. Energy generation, stellar lifetimes, star clusters. A qualitative view of star formation & evolution of low & high mass stars. End points of stellar evolution, white dwarf stars, supernovae, neutron stars & black holes, synthesis of the chemical elements.

The Milky Way: constituents & structure, central black hole, formation models. Properties of galaxies. The Hubble sequence. Active galaxies. The expanding universe, galaxy clusters, dark matter. Galaxy assembly. Large scale structure, the distance scale, cosmic microwave background, probes of dark energy, the hot big bang, age of the Universe, concordance cosmology.

[Note that knowledge of the prelims mechanics and special relativity courses will be assumed.]

S03: Quantum Ideas

The success of classical physics, measurements in classical physics. The nature of light, the ultraviolet catastrophe, the photoelectric effect and the quantisation of radiation. Atomic spectral lines and the discrete energy levels of electrons in atoms, the Frank-Hertz experiment and the Bohr model of an atom.

Magnetic dipoles in homogeneous and inhomogeneous magnetic fields and the Stern-Gerlach experiment showing the quantisation of the magnetic moment. The Uncertainty principle by considering a microscope and the momentum of photons, zero point energy, stability and size of atoms.

Measurements in quantum physics, the impossibility of measuring two orthogonal components of magnetic moments. The EPR paradox, entanglement, hidden variables, non-locality and Aspect's experiment, quantum cryptography and the BB84 protocol. Schrödinger's cat and the many-world interpretation of quantum mechanics. Interferometry with atoms and large molecules. Amplitudes, phases and wavefunctions.

Interference of atomic beams, discussion of two-slit interference, Bragg diffraction of atoms, quantum eraser experiments. A glimpse of quantum engineering and quantum computing.

S04: Energy Studies

Historical development of power generation, global issues. Conservation laws. Application of thermodynamic reasoning topower 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 coordinates; configuration space. Application to motion in strange co-ordinate systems, particle in an electromagnetic field, normal modes, rigid bodies. Noether's theorem and conservation laws.

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

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

*** Note: the above 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" andDNA 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.

Single-molecule experimental techniques: patch-clamp, Fluorescence microscopy, optical tweezers, atomic force microscopy.

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 and bound states. Elements of the inverse scattering problem. Analytic properties of the S-matrix. Dispersion relations. Green's functions methods in scattering theory. Perturbation theory. The Lippmann-Schwinger equation. Born series. Variational methods. Scattering by a central potential. Method of partial waves, the phase shift. Jost functions. Unitarity and the optical theorem. Quasi-stationary states and their decay. Relativistic wave equations: the Klein-Gordon equation, the Dirac equation, their properties and solutions. Relativistic scattering.

S19: Unifying Physics of Accelerators, Lasers and Plasma*

Basics of accelerators. Laser designs and methods to generate short and powerful laser pulses. Plasma basics and laser-matter interaction; novel laser-plasma acceleration methods; traditional acceleration methods; transverse dynamics and focusing, including plasma-assisted. Synchrotron radiation and design of compact laser-plasma light sources. Design of Free Electron Lasers: national scale as well as compact based on plasma acceleration. Design of conventional particle therapy facilities and those based on plasma acceleration; effect of radiation on DNA; medical imaging including phase contrast methods. Methods for advanced manipulation of beams of particles and of light; designs of colliders which could be built after LHC; designs of future light sources.

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.

S29: Exploring Solar Systems

The planets in our Solar system in context and with other solar systems, basic concepts including overview of orbits. Description of data sources (types of space missions, ground based observations, remote sensing and in-situ measurements). Solar system formation, planetary interiors, connection to observed terrestrial planetary surfaces, magnetic field (presence of dynamos), impact and cratering processes, introductory concepts in seismology. Planetary atmospheres, including basic derivations of thermodynamic concepts such as lapse rates, thermal structure, introduction to radiative transfer. Clouds and basic dynamics/ thermal wind equation. Applications of key concepts to exoplanets, next steps in planetary science, future exploration.

*** to be ratified by the Physics Teaching Faculty Michaelmas 2015**

Syllabuses for Major Options - Part C

Note that for most options only short versions of the syllabus are given here.
General familiarity with the compulsory topics in the syllabuses for Parts A and B will be assumed.
More specific prerequisites may be indicated in the sections for the individual options
and more details are given on the Major Options website pages
http://www.physics.ox.ac.uk/Teach/Major_Options/default.htm.

Each of the physics C papers is a 3-hour paper, for which there is an additional 10 minutes reading time answer 4 questions from 8 with each question worth 25 marks.

C1: Astrophysics

The Big Bang and relativistic cosmology; current cosmological models; large scale structure; anisotropies in the Cosmic Microwave Background.

The Milky Way and other galaxies: properties, formation and evolution; dark matter; gravitational lensing

Physics of interactions between high energy particles and radiation (synchrotron, inverse-Compton, thermal bremsstrahlung); the Eddington limit; accretion onto compact objects; black holes, active galaxies and relativistic jets.

Late stages of stellar evolution; massive stars; supernovae, millisecond pulsars, hypernovae, gamma-ray bursts; compact binaries; the origin of elements, chemical evolution of the Universe.

The interstellar and intergalactic medium; star and planet formation; continuous and absorption line spectra; emission line formation and analysis; cosmic dust and extinction; stellar photospheres.

C2: Laser Science and Quantum Information Processing

Knowledge of the laser physics covered in paper B3 will be assumed.

Lasers: Line broadening mechanisms, linewidths and gain saturation. Q-switched operation. Modelocking. Frequency control and frequency locking. Solid state lasers. Semiconductor lasers. Fibre lasers. Ultrafast lasers: chirped pulse amplification, terawatt and petawatt laser systems.

Examples of laser systems: Nd:Glass, Nd:YAG. Ti:sapphire; Er:Glass fibre lasers and the Er-doped fibre amplifier (EDFA); AlGaAs and GaN semiconductor lasers.

Optics: Diffraction. Ray matrices and Gaussian beams. Cavity eigenfunctions: the concept of cavity mode, the stability criterion, cavity design. Beamsplitters. Transverse coherence and Michelson stellar interferometer. Longitudinal coherence: optical coherence tomography and Fourier transform spectroscopy. (Not correlation functions, Wiener-Khintchine theorem). Optics in Structured Materials: optical fields in planar waveguides and fibres.

Non-linear Optics: Crystal symmetries and the linear electrooptic tensor. Amplitude and phase modulation of light using the linear electro-optic effect. Second harmonic generation. Critical,non-critical and quasi-phase matching. Sum and difference frequency generation and optical parametric down conversion.

Quantum optics: Elementary introduction to quantum fields and photons. Light-matter interactions and the Jaynes-Cummings model. Generation and detection of nonclassical states of light: parametric down conversion and photon entanglement, photon action at a beam splitter, bosonic statistics. Berry and Pancharatnam phases.

Quantum mechanics and Quantum Bits: Two level systems as quantum bits. Superposition states, the Bloch sphere, mixed states, density matrices, Pauli matrices. Single qubit dynamics (gates): NOT, square root of NOT-gate, Hadamard, phase shift, networks of gates, the measurement gate.

Implementations: atom/ion in a laser field, photon polarisation, spin in a magnetic field. Mechanisms: Raman transitions, Rabi flopping, Ramsey fringes, spin echoes.

Decoherence (simple treatment). Separable and inseparable (entangled) states of two spin systems. Two qubit gates: controlled-NOT, controlled-phase. Universality of gates (result only). Characterising an unknown state, state and gate fidelity (very basic), the no-cloning theorem. EPR, the four Bell states, the Bell inequalities.

Quantum Computation: Reversible computation with unitary gates. Quantum parallelism and readout. The Deutsch and Grover algorithms. Other quantum algorithms: Shor (result only), quantum simulation. Error correction (3 qubit code for phase or flip only) and decoherence free subspaces. DiVincenzo criteria. Experimental methods with trapped atoms and ions. The controlled phase gate by "collisions". Optical lattices and massive entanglement. Experimental methods with NMR. Qualitative treatment of other quantum computing technologies.

Quantum Communication: Elementary ideas about information content. Quantum dense coding. Testing Bell inequalities. Quantum key distribution, the BB84 protocol and detecting eavesdropping (only intercept/resend strategy). EPR based cryptography. Fibre and free space cryptography, polarisation and phase encoding. Phase encoding methods. Quantum teleportation and entanglement swapping.

C3: Condensed Matter Physics

Symmetry. Crystal structure, reciprocal lattice, Brillouin zones — general treatment for non-orthogonal axes. X-ray, neutron and electron diffraction. Disordered materials.

Lattice dynamics. Measurement of phonon dispersion. Thermal properties of crystals. Phase transitions. Soft modes.

Electronic structure of solids. Semiconductors. Transport of heat and electrical current. Quasiparticles, Fermi surfaces and interactions between electrons and magnetic fields. Low-dimensional structures.

Lorentz oscillator model. Optical response of free electrons and lattice. Optical transitions in semiconductors. Excitons.

Isolated magnetic ions. Crystal field effects. Magnetic resonance. Exchange interactions. Localized and itinerant magnets. Magnetic ordering and phase transitions, critical phenomena, spin waves. Domains.

Conventional and unconventional superconductors. Thermodynamic treatment. London, BCS and Ginzburg–Landau theories. Flux quantization, Josephson effects, quantum interference.

C4: Particle Physics

The content of the sub-atomic physics (B4) and the symmetry & relativity (B2) syllabus will be assumed, as will familiarity with the Fermi Golden Rule and the Breit-Wigner resonance formula

Quark structure of hadrons. Deep inelastic scattering, the quark-parton model and quantum chromodynamics (QCD). Heavy quark states.

Elementary introduction to radio-frequency acceleration and beam optics. Colliders and fixed targets. Event rates and luminosity. Triggering and event selection. Physics of particle detectors, wire chambers, silicon detectors, calorimeters, muon chambers, Cerenkov radiation detectors. Particle identification. Applications to real experiments.

Introduction to relativistic quantum mechanics. Matrix elements. Discrete and continuous symmetries. Gauge symmetries and the Standard Model.

Electroweak interactions, charged and neutral currents. Electroweak symmetry breaking. W and Z bosons. Fundamental particles of the Standard Model. Discovery of the top quark and searches for the Higgs boson.

Oscillations in the K^0 and B^0 systems, CP violation. Neutrino oscillations. Ideas beyond the Standard Model and future projects.

C5: Physics of Atmospheres and Oceans

Composition, Thermodynamics, Clouds and Chemistry

Atmospheric composition and structure. Atmospheric chemistry: kinetics, radiation and photochemistry, catalytic cycles, heterogeneous processes, the Ozone Hole. Dry thermodynamics: hydrostatic equation, lapse rate, potential temperature, entropy. Moist thermodynamics: Clausius-Clapeyron equation, phase diagrams, cloud formation. Convection: buoyancy, parcel theory, atmospheric stability, thermodynamic diagrams, potential energy, radiative convective equilibrium, quasi-equilibrium hypothesis. Cloud microphysics: Kelvin equation, Raoult's law, Köhler theory, spherical and non-spherical hydrometeor growth, freezing modes, ice nucleation, ice crystal habit. Cloud morphology and occurrence. Planetary clouds.

Geophysical fluid dynamics

Rotating frames of reference. Geostrophic and hydrostatic balance. Pressure coordinates. Shallow water and reduced gravity models, f and β–planes, potential vorticity. Inertia-gravity waves, dispersion relation, phase and group velocity. Rossby number, equations for nearly geostrophic motion, Rossby waves, Kelvin waves. Linearised equations for a stratified, incompressible fluid, internal gravity waves, vertical modes. Quasigeostrophic approximation: potential vorticity equation, Rossby waves, vertical propagation and trapping. Eady model of baroclinic instability, qualitative discussion of frontogenesis. Overview of large-scale structure and circulation of atmospheres and oceans, poleward heat transport. Wind-driven ocean circulation: Ekman transport and upwelling, Sverdrup balance and ocean gyres, Stommel's model of western boundary currents. Meridional overturning circulation: water mass formation, role of mechanical forcing, Stommel-Arons model and deep western boundary currents, multiple equilibria. Angular momentum and Held-Hou model of Hadley circulations. Applications to Mars and slowly-rotating planets. Giant planets: Multiple jets, stable eddies and free modes.

Radiative transfer and radiative forcing

Radiative transfer in the atmosphere: Black body radiation, Earth's emission spectrum, the solar spectrum, the total solar irradiance, photochemistry, molecular spectra, line shape, radiative properties of clouds and aerosols. Rayleigh & Mie scattering, the equation of radiative transfer, band models. Weighting functions.

Observations and inverse methods

Introduction to remote sounding and inverse problems. Simple random processes as models of measurement and atmosphere/ocean behaviour, exactly-determined, over-determined and under-determined systems, least-squares estimation, matrix formulation, likelihood, expectation, variance and covariance. Gauss-Markov theorem, Bayes' theorem, Kalman gain matrix. Examples from atmospheric remote sounding and ocean altimetry, time-dependent inverse problems, the Kalman filter, error growth, implications for weather analysis, forecasting and predictability. Infrared instruments and techniques for remote sensing of climate variables. Satellite and ground-based instrumentation.

C6: Theoretical Physics

The mathematical description of systems with an infinite number of degrees of freedom: functionals, functional differentiation, and functional integrals. Multi-dimensional Gaussian integrals. Random fields: properties of a Gaussian field. Perturbation theory for non-Gaussian functional integrals. Path integrals and quantum mechanics. Treatment of free particle and of harmonic oscillator.

Classical field theory: fields, Lagrangians and Hamiltonians. The least action principle and field equations. Space-time and internal symmetries: U(1) example, Noether current. The idea of an irreducible representation of a group. Irreducible representations of SU(2) and application to global internal symmetry. Simple representations of the Lorentz group via SU(2)xSU(2) without proof.U(1) gauge symmetry, action of scalar QED and derivation of Maxwell's eqns in covariant form.

Landau theory and phase transitions: phase diagrams, first-order and continuous phase transitions. Landau-Ginsburg-Wilson free energy functionals. Examples including liquid crystals. Critical phenomena and scaling theory.

The link between quantum mechanics and the statistical mechanics of one-dimensional systems via Wick rotation. Transfer matrices for one-dimensional systems in statistical mechanics.

Stochastic processes and path integrals: the Langevin and Fokker-Planck equation. Brownian motion of single particle. Rouse model of polymer dynamics.

Canonical quantisation and connection to many body theory: quantised elastic waves; quantisation of free scalar field theory; many-particle quantum systems.

Path integrals and quantum field theory: generating functional and free particle propagator for scalar and U(1) gauge fields (in Lorentz gauge).

Perturbation theory at tree level for decay and scattering processes. Examples from pure scalar theories and scalar QED. Goldstone theorem.

Canonical transformations in quantum field theory: Bogoliubov transformations applied to bose condensates, magnons in antiferromagnets, and to BCS theory.

C7: Biological Physics

Biological materials and structures: cells, DNA and RNA, proteins, lipid bilayers. Protein structure and folding. Mechanical properties of biopolymers.

Brownian motion, chemical reactions, biological processes and bio-energetics, molecular machines.

Chromosomes, DNA compaction and packaging. Transcription and transcriptional regulation. Biological networks.

Membranes and membrane proteins: electrostatic interactions, dispersion and hydration forces. Ions and counterions; ion channels, photo-receptors and neuroreceptors. Neurons and neuronal signalling.

Single-molecule techniques, patch-clamp, fluorescence microscopy, optical tweezers, magnetic tweezers, atomic force microscopy.

SPECIAL REGULATIONS FOR THE PRELIMINARY EXAMINATION IN PHYSICS +

A

1. The subject of the Preliminary Examination in Physics shall be Physics, including basic practical and mathematical techniques.

2. The number of papers and other general requirements of the Preliminary Examination in Physics shall be as prescribed by regulation from time to time by the Mathematical, Physical and Life Sciences Board.

B

1. Candidates in Physics must offer four Compulsory Papers at one examination, provided that a candidate who has failed in one or two papers may offer that number of papers at a subsequent examination. The titles of the papers shall be:

CP1: Physics 1

CP2: Physics 2

CP3: Mathematical Methods 1

CP4: Mathematical Methods 2.

Their syllabuses shall be approved by the Faculty of Physics and shall be published in the Physics Course Handbook by the Faculty of
Physics not later than the beginning of Michaelmas Full Term for examination three terms thence.

2. In addition to the four papers of clause 1, a candidate in Physics shall be required
(i) to submit to the Moderators such evidence as they require of the successful completion of practical work normally pursued during the three terms preceding the examination, and
(ii) to offer a written paper on one Short Option.

3. Candidates shall be deemed to have passed the examination if they have satisfied the Moderators in the four compulsory papers either at a single examination or at two examinations in accordance with the proviso to clause 1, and provided further that the same number of papers as were failed at the first sitting have been passed at the same attempt at a subsequent examination.

4. In the case of candidates who offer all four papers of clause 1, the Moderators shall publish the names only of those who have satisfied them in two or more papers. Candidates whose names do not appear on the pass list must offer four papers at a subsequent examination. In the case of candidates who, in accordance with the proviso to clause 1, offer one or two papers, the Moderators shall publish the names only to those who have satisfied them in each of the papers offered.

5. The Moderators may award a distinction to candidates of special merit who have satisfied them in all four papers of clause 1 at the single examination and in the requirements of clause 2.

6. Failure to complete practical work under clause 2(i), without good reason, will be deemed by the Moderators as failure in the Preliminary Examination and the candidate will be required to complete the outstanding practicals either by examination or by completing them alongside second year study, before entry to the Part A examination will be permitted. In these circumstances, distinction at the Preliminary Examination will not be possible.

7. The list of Short Option subjects in clause 2(ii) and their syllabuses shall be approved by the Faculty of Physics and shall be published in the Physics Course Handbook by the Faculty of Physics not later than the beginning of Michaelmas Full Term for examination three terms thence.

8. With respect to subjects under clause 2(ii) a candidate may propose to the Head of the Teaching Faculty of Physics or deputy, not later than the last week of Michaelmas Full Term preceding the examination, another subject paper. Candidates shall be advised of the decision by the end of the first week of the subsequent Hilary Full **Term.**

9. Except for papers for which their use is forbidden, the Moderators will permit the use of any hand-held calculator subject to the conditions set out under the heading 'Use of calculators in examinations' in the *Regulations for the Conduct of University Examinations* and further elaborated in the Course Handbook.

+ **Note**: The examination regulations for Physics Prelims and Finals Honour School are included for convenience, however the definitive versions are those published by the University (*Examination Regulations* at http://www.admin.ox.ac.uk/examregs/ and 'The Grey Book') each academic year.

REGULATIONS FOR THE HONOUR SCHOOL OF PHYSICS +

A

1. (1) The subject of the Honour School in Physics shall be the study of Physics as an experimental science.

(2) *Physics (four year course)*

The examination shall be in three parts, A, B, C, taken at times not less than three, six and nine terms, respectively after passing the First Public Examination.

In order to proceed to Parts B and C of the four-year course in physics a minimum standard of achievement in Part A may be required, as determined by the Faculty of Physics from time to time. Any such requirement shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term of the academic year preceding the year of the Part A examination. Names of those satisfying the requirement shall be published by the Examiners.

(3) *Physics (three year course)*

The examination shall be in two parts, A and B, taken at times not less than three and six terms, respectively, after passing the First Public Examination.

2. (1) The name of a candidate in either the three-year course or the four-year course shall not be published in a Class List until he or she has completed all parts of the respective examinations.

(2) The Examiners in Physics for the three-year course or the four-year course shall be entitled to award a pass or classified Honours to candidates in the Second Public Examination who have reached a standard considered adequate; the Examiners shall give due consideration to the performance in all parts of the respective examinations.

(3) (a) A candidate who obtains only a pass or fails to satisfy the Examiners may enter again for Part B (three-year course) or Part C (four-year course) of the examination on one, but not more than one, subsequent occasion.

(b) Part A (three-year and four-year courses) and Part B (four-year course) shall be entered on one occasion only.

(4) A candidate adjudged worthy of Honours in the Second Public Examination for the four-year course in Physics may supplicate for the Degree of Master of Physics provided that the candidate has fulfilled all the conditions for admission to a degree of the University.

(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.

3. The examination shall be partly practical: this requirement shall normally be satisfied by the Examiners' assessment of the practical work done by candidates during their course of study; exceptionally, the Examiners may require a candidate to take a practical examination.

4. No candidate shall be admitted to examination in this school unless he or she has either passed or been exempted from the First Public Examination.

5. (1) The Examination in Physics shall be under the supervision of the Mathematical, Physical and Life Sciences Board.

(2) The board shall have power, subject to this decree, from time to time to frame and to vary regulations for the different parts and subjects of the examination.

Transfer to the Honour School of Mathematical and Theoretical Physics

6. Subject to the regulations for the Honour School in Mathematical and Theoretical Physics, candidates on the four-year course in Physics may apply to the Supervisory Committee for Mathematics and Physics to transfer, after their Part B examination, to the Honour School of Mathematical and Theoretical Physics for their Part C examination. Such a candidate will need to achieve at least an upper second class or higher at the end of Part B, and be accepted by the Supervisory Committee for Mathematics and Physics under the procedures referred to in the regulations for the Master of Mathematical and Theoretical Physics and set out in the course handbook for that degree. Acceptance is not automatic. As specified in the regulations for that degree, Part C in Mathematical and Theoretical Physics must be taken in the academic year following the candidate's Part B examination, and on successful completion o Part C of the Honour School of Mathematical and Theoretical Physics candidates will be awarded the Master of Mathematics and Physics in Mathematical and Theoretical Physics.

7. The Handbook for Mathematical and Theoretical Physics shall, where relevant, set out the options that candidates should follow to maximize their chances of being accepted for transfer to Mathematical and Theoretical Physics for their Part C examination. This Handbook shall be available by the start of Michaelmas Term in the year in which a candidate starts Part A in Physics.

8. A candidate who has transferred from the Honour School of Physics to the Honour School of Mathematical and Theoretical Physics for their Part C examination in accordance with cl.9 above is permitted transfer to the Honour School of Physics for their Part C examination up to the end of Week 4 of the Michaelmas Term in which he or she first registered for Part C in the Honour School of Mathematical and Theoretical Physics, so long as that candidate has not opted to supplicate for the degree of Bachelor of Arts in Physics under the regulations for the Honour School of Mathematical and Theoretical Physics.

9. The regulations for the Honour School of Mathematical and Theoretical Physics set out how the results obtained in Parts A and B in the Honour School of Physics are published for candidates who transfer to the Honour School of Mathematical and Theoretical Physics for their Part C examination.

B

In the following 'the Course Handbook' refers to the Physics Undergraduate Course Handbook, published annually at the start of Michaelmas Term by the Faculty of Physics.

Candidates will be expected to show knowledge based on practical work.

The Examiners will permit the use of any hand-held calculator subject to the conditions set out under the heading 'Use of calculators in examinations' in the Regulations concerning the Conduct of University Examinations and further elaborated in the Course Handbook.

The various parts of the examinations for the three and four year courses shall take place in Trinity Term of the year in question and, unless otherwise stated, deadlines shall apply to the year in which that part is taken.

Part A – for candidates on both the three-year and the four-year course

1. In Part A

(a) the candidate shall be required

(i) to offer three written papers on the Fundamental Principles of Physics, and

(ii) to submit to the Examiners such evidence as they require of the successful completion of practical work normally pursued during the three terms preceding the examination, and

(iii) to offer a written paper on one Short Option.

(b) A candidate may also offer a written paper on a second Short Option, in which case the candidate need only submit evidence of the successful completion of practical work normally pursued during one and a half terms of the three terms specified in cl. 1(a)(ii).

2. The titles of the written papers of cl. 1(a)(i) are given in the Schedule below. Their syllabuses shall be approved by the Faculty of Physics and shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence.

3. The list of Short Option subjects in cl. 1(a)(iii), 1(b), and their syllabuses shall be approved by the Faculty of Physics and shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence.

4. With respect to cl. 1(a)(iii) a candidate may take, as alternative to the written examination, an assessed course of instruction in a foreign language. A candidate proposing to take this alternative must have the proposal approved by the Head of the Teaching Faculty of Physics or deputy and by the Director of the Language Centre or deputy, by the end of the first week of Hilary Full Term preceding the examination. 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.

5. With respect to subjects under cl. 1(a)(iii) a candidate may propose to the Head of the Teaching Faculty of Physics or deputy, not later than the fourth week of Michaelmas Full Term preceding the examination, either to offer another subject paper, or to offer instead a written account of extended practical work, in addition to that specified in cl.1(a)(ii). Candidates will be advised of the decision by the end of eighth week of that term.

Schedule

Fundamental Principles (Part A)

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

Part B for candidates on the three-year course

1. In Part B

(a) the candidate shall be required

(i) to offer four written papers on Physics, and

(ii) to submit to the Examiners such evidence as they require of the successful completion of practical work normally pursued during three terms in the academic year of the examination, and

(iii) to offer a written paper on one Short Option.

(b) a candidate may also offer a written paper on a second Short Option, in which case the candidate need only submit evidence of the successful completion of practical work normally pursued during one and a half terms of the three terms specified in cl. 1(a)(ii).

(c) to offer a project report on practical work or other work undertaken in the academic year in which the examination takes place on a subject approved by the Head of the Teaching Faculty of Physics or deputy.

(d) candidates may be examined by viva voce.

2. The titles of the written papers of cl. 1(a)(i) are given in the Schedule below. Their syllabuses shall be approved by the Faculty of Physics and shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence. The four papers offered shall include B3, B4 and B6.

3. The list of Short Option subjects in cl. 1(a)(iii), cl. 2 and their syllabuses shall be approved by the Faculty of Physics and shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence.

4. In cl. 1(a)(ii), practical work may be replaced by project work, if an appropriate supervisor is available. The subject, duration, and replacement value shall be approved by the Head of the Teaching Faculty of Physics or deputy, by the end of Michaelmas Full Term.

5. With respect to cl. 1(a)(iii) a candidate may take, as alternative to the written examination, an assessed course of instruction in a foreign language. A candidate proposing to take this alternative must have the proposal approved by the Head of the Teaching Faculty of Physics or deputy and by the Director of the Language Centre or deputy, by the end of the first week of Hilary Full Term. 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.

6. With respect to subjects under cl. 1(a)(iii) a candidate may propose to the Head of the Teaching Faculty of Physics or deputy, not later than the fourth week of Michaelmas Full Term preceding the examination, another subject paper. Candidates shall be advised of the decision by the end of eighth week of that term.

Schedule

Physics (Part B)

Six papers, B1 to B6 as follows:

B1. Flows, Fluctuations and Complexity

B2. Symmetry and Relativity

B3. Quantum, Atomic and Molecular Physics

B4. Sub-Atomic Physics

B5. General Relativity and Cosmology

B6. Condensed-Matter Physics

Part B for candidates on the four-year course

1. In Part B

(a) the candidate shall be required

(i) to offer six written papers on Physics, and

(ii) to submit to the Examiners such evidence as they require of the successful completion of practical work normally pursued during the three terms preceding the examination, and

(iii) to submit to the Examiners such evidence as they require of the successful completion of practical work normally pursued during the three terms preceding the examination, and
(iii) to offer a written paper on one Short Option.

(b) A candidate may also offer a written paper on a second Short Option, in which case the candidate need only submit evidence of the successful completion of practical work normally pursued during one and a half terms of the three terms specified in cl. 1(a)(ii).

2. The titles of the written papers of cl. 1(a)(i) are given in the Schedule below. Their syllabuses shall be approved by the Faculty of Physics and shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence.

3. The list of Short Option subjects in cl. 1(a)(iii), 1(b) and their syllabuses shall be approved by the Faculty of Physics and shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence.

4. In cl. 1(a)(ii), practical work may be replaced by project work, if an appropriate supervisor is available. The subject, duration, and replacement value shall be approved by the Head of the Teaching Faculty of Physics or deputy, by the end of Michaelmas Full Term.

5. With respect to cl. 1(a)(iii) a candidate may take, as alternative to the written examination, an assessed course of instruction in a foreign language. A candidate proposing to take this alternative must have the proposal approved by the Head of the Teaching Faculty of Physics or deputy and by the Director of the Language Centre or deputy, by the end of the first week of Hilary Full Term preceding the examination. 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.

6. With respect to subjects under cl. 1(a)(iii) a candidate may propose to the Head of the Teaching Faculty of Physics or deputy, not later than the fourth week of Michaelmas Full Term preceding the examination, either to offer another subject paper, or to offer instead a written account of extended practical work, in addition to that specified in cl.1(a)(ii). Candidates will be advised of the decision by the end of eighth week of that term.

Schedule

Physics (Part B)

Six papers, B1 to B6 as follows:

B1. Flows, Fluctuations and Complexity

B2. Symmetry and Relativity

B3. Quantum, Atomic and Molecular Physics

B4. Sub-Atomic Physics

B5. General Relativity and Cosmology

B6. Condensed-Matter Physics

Part C

1. In Part C the candidate shall be required to offer

(a) written papers on each of two Major Options, and

(b) a project report on either advanced practical work, or other advanced work.

Candidates may also be examined viva voce.

2. In cl. 1(a), the Major Options and their syllabuses shall be approved by the Faculty of Physics and the Physics Academic Committee. The titles of the Major Options are given in the Schedule below and the syllabuses shall be published in the Course Handbook not later than the beginning of Michaelmas Full Term for the examination three terms thence.

3. With respect to subjects under cl. 1(a) a candidate may propose to the Head of the Teaching Faculty of Physics or deputy, not later than the fourth week of Trinity Full Term in the academic year preceding the examination, another subject paper or papers. Candidates will be advised of the decision by the end of eighth week of that term.

4. In cl. 1(b), the proposed nature of the practical or other advanced work and its duration shall be submitted for approval to the Head of the Teaching Faculty of Physics or deputy with the agreement of the Physics Academic Committee.

Schedule

Major Options (Part C)

C1: Astrophysics

C2: Laser Science and Quantum Information Processing

C3: Condensed Matter Physics

C4: Particle Physics

C5: Physics of Atmospheres and Oceans

C6: Theoretical Physics

C7: Biological Physics

Appendix J

University Policy on Intellectual Property Rights

The University in its Statutes claims ownership of certain forms of intellectual property which students create in the course of, or incidentally to, their studies. There are other arrangements in the University's regulations for protecting and exploiting this property, and sharing the commercial exploitation revenues with the student originators. By accepting a place at Oxford as a student, you agree to be legally bound by these provisions.

Here is the extract of the text of the Statute relating to intellectual property. The procedures for the administration of the University's policy, as set out in the relevant regulations, are available at http://www.admin.ox.ac.uk/researchsupport/ip/ these explain the approved arrangements for revenue-sharing. Further information may be obtained from iprm@admin.ox.ac.uk.

Statute XVI: Property, Contracts, and Trusts

Part B: INTELLECTUAL PROPERTY

5. (1) The University claims ownership of all intellectual property specified in section 6 of this statute which is devised, made, or created:
(a) by persons employed by the University in the course of their employment; (b) by student members in the course of or incidentally to their studies;
(c) by other persons engaged in study or research in the University who, as a condition of their being granted access to the University's premises or facilities, have agreed in writing that this Part shall apply to them; and
(d) by persons engaged by the University under contracts for services during the course of or incidentally to that engagement.
(2) The University's rights under sub-section (1) above in relation to any particular piece of intellectual property may be waived or modified by agreement in writing with the person concerned.

6. The intellectual property of which ownership is claimed under section 5 (1) of this statute comprises:
(1) works generated by computer hardware or software owned or operated by the University;
(2) works created with the aid of university facilities including (by way of example only) films, videos, photographs, multimedia works, typographic arrangements, and field and laboratory notebooks;
(3) patentable and non-patentable inventions;
(4) registered and unregistered designs, plant varieties, and topographies;
(5) university-commissioned works not within (1), (2), (3), or (4);
(6) databases, computer software, firmware, courseware, and related material not within (1), (2), (3), (4), or (5), but only if they may reasonably be considered to possess commercial potential; and
(7) know-how and information associated with the above.

7. The University will not assert any claim to the ownership of copyright in:
(1) artistic works not listed in sub-section (2) of section 6 of this statute, books, articles, plays, lyrics, scores, or lectures, apart from those specifically commissioned by the University;
(2) audio or visual aids to the giving of lectures;
(3) student theses, exercises and answers to tests and examinations save to the extent that they contain intellectual property claimed by the University under subsection (6) of section 6 of this statute; or
(4) computer-related works other than those specified in section 6 of this statute.

8. For the purpose of sections 6 and 7 of this statute, 'commissioned works' are works which the University has specifically employed or requested the person concerned to produce, whether in return for special payment or not. 'Commissioned works' explicitly exclude (i) lectures delivered by University Lecturers, Departmental Lecturers and the holders of University Chairs in fulfilment of obligations in their contracts of
employment and (ii) works commissioned by the University Press in the course of its publishing business
(save as may be separately agreed between the University Press and the person concerned).

9. Council may make regulations:
(1) defining the classes of persons or naming individuals to whom section 5 (1) (c) of this statute shall apply;
(2) requiring student members and such other persons as may be specified in regulations to sign any documents necessary in order to give effect to the claim made by the University in this Part and to waive any rights in respect of the subject-matter of the claim which may be conferred on them by Chapter IV of Part 1 of the Copyright, Designs and Patents Act 1988; and
(3) generally for the purposes of this Part.

10. This Part shall apply to all intellectual property devised, made, or created on or after 1 October 2000 and is subject to the provisions of the Patents Act 1977.

Appendix K

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The Copyright Licensing Agency

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Appendix L (Lecture and Practical Feedback Forms - SPECIMEN)

PJCC **LECTURE** FEEDBACK FORM

Lecture Attendance

	none	only the first few	some to all	
I have attended...	○	○	○	...of the lectures.

Lectures

Please indicate how strongly you agree or disagree with each of the following statements...

1 = strongly disagree, 5 = strongly agree	**1**	**2**	**3**	**4**	**5**
The lectures helped my understanding of the subject	○	○	○	○	○
The lecturer made this lecture course engaging and interesting.	○	○	○	○	○
The lectures were easy to follow and well structured.	○	○	○	○	○
	too slow		**...**		**too fast**
I would describe the pace of the lectures as...	○	○	○	○	○

If you have any other comments on the lectures, or this lecture course in general, please write them below...

Lecture Materials: Printed Notes and Problem Sets

Please indicate how strongly you agree or disagree with each of the following statements...

1 = strongly disagree, 5 = strongly agree	**1**	**2**	**3**	**4**	**5**	**N/A**
The lecturer's notes were useful and well structured.	○	○	○	○	○	○
The lecturer's problem sets were interesting and improved my understanding of the subject.	○	○	○	○	○	○

If you would like to report errata in the lecture notes and problems sets or suggest any other improvements, please use the space below...

PJCC **PRACTICAL COURSE** FEEDBACK FORM

Name of Lab ...

Please rate these practicals on a scale of 1 out 5 through to 5 out of 5 when answering the following...

	1	**2**	**3**	**4**	**5**
How much did these labs help with your understanding of the physics course?	○	○	○	○	○
How useful were these labs in developing your experimental skills?	○	○	○	○	○
How interesting and enjoyable did you find these labs?	○	○	○	○	○
1 = too little, 5 = too much	**1**	**2**	**3**	**4**	**5**
How much theory was there in these labs?	○	○	○	○	○
How much time did these labs take to complete?	○	○	○	○	○

Use the space below for any comments on the helpfulness of the demonstrators or any particular experiments...

Complaints and Appeals

Complaints and appeals

Complaints and academic appeals within the Department of Physics

The University, the **MPLS Division** and the **Department of Physics** all hope that provision made for students at all stages of their course of study will make the need for complaints (about that provision) or appeals (against the outcomes of any form of assessment) infrequent.

Nothing in the University's complaints procedure precludes 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). This is often the simplest way to achieve a satisfactory resolution.

Many sources of advice are available within colleges, within faculties/departments and from bodies like Student Advice Service provided by OUSU or the Counselling Service, which have extensive experience in advising students. You may wish to take advice from one of these 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 chairman of the Teaching Committee Head of Teaching, **Prof Jonathan Jones**. Within the **Department of Physics** the officer concerned will attempt to resolve your concern/complaint informally.

If you are dissatisfied with the outcome, then you may take your concern further by making a formal complaint to the University Proctors. The procedures adopted by the Proctors for the consideration of complaints and appeals are described on the Proctors' webpage (www.admin.ox.ac.uk/proctors/complaints/proceduresforhandlingcomplaints), the Student Handbook (www.admin.ox.ac.uk/proctors/info/pam) and the relevant Council regulations (www.admin.ox.ac.uk/statutes/regulations/247-062.shtml)

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 defined as a formal questioning of a decision on an academic matter made by the responsible academic body.

For undergraduate or taught graduate courses, a concern which might lead to an appeal should be raised with your college authorities and the individual responsible for overseeing

your work. It must not be raised directly with examiners or assessors. If it is not possible to clear up your concern in this way, you may put your concern in writing and submit it to the Proctors via the Senior Tutor of your college.

For the examination of research degrees, or in relation to transfer or confirmation of status, your concern should be raised initially with the Director of Graduate Studies. Where a concern is not satisfactorily settled by that means, then you, your supervisor, or your college may put your appeal directly to the Proctors.

As noted above, the procedures adopted by the Proctors in relation to complaints and appeals are are described on the Proctors' webpage (www.admin.ox.ac.uk/proctors/complaints/proceduresforhandlingcomplaints), the Student Handbook (www.admin.ox.ac.uk/proctors/info/pam) and the relevant Council regulations (www.admin.ox.ac.uk/statutes/regulations/247-062.shtml).

Please remember in connection with all the academic appeals that:

- The Proctors are not empowered to challenge the academic judgement of examiners or academic bodies.
- The Proctors can consider whether the procedures for reaching an academic decision were properly followed; i.e. whether there was a significant procedural administrative error; whether there is evidence of bias or inadequate assessment; whether the examiners failed to take into account special factors affecting a candidate's performance.
- On no account should you contact your examiners or assessors directly.

Appendix N

Useful Department Contacts

Head of the Physics Teaching Faculty	Prof. J A Jones	72247	jonathan.jones@qubit.org
Assistant Head of Teaching (Academic)	Mrs C Leonard-McIntyre	72407	carrie.leonard-mcintyre@physics.ox.ac.uk
Head of Physics Teaching Laboratories	Dr K Aplin	73491	karen.aplin@physics.ox.ac.uk
Physics and Philosophy contact	Dr C W P Palmer	72276	christopher.palmer@physics.ox.ac.uk
Teaching Faculty Administration Officer	Miss H Glanville	72369	hannah.glanville@physics.ox.ac.uk
4^{th} Year Major Options Coordinators	https://weblearn.ox.ac.uk/portal/hierarchy/mpls/physics/teaching/undergrads/majoroptions		
Disabilitity Contact	Mrs C Leonard-McIntyre	72407	carrie.leonard-mcintyre@physics.ox.ac.uk
Teaching Faculty e-mail address			TeachingAdmin@physics.ox.ac.uk
PJCC Website	https://pjcc.physics.ox.ac.uk/		