Photo: Alan Segar

2011 - 2012

Physics

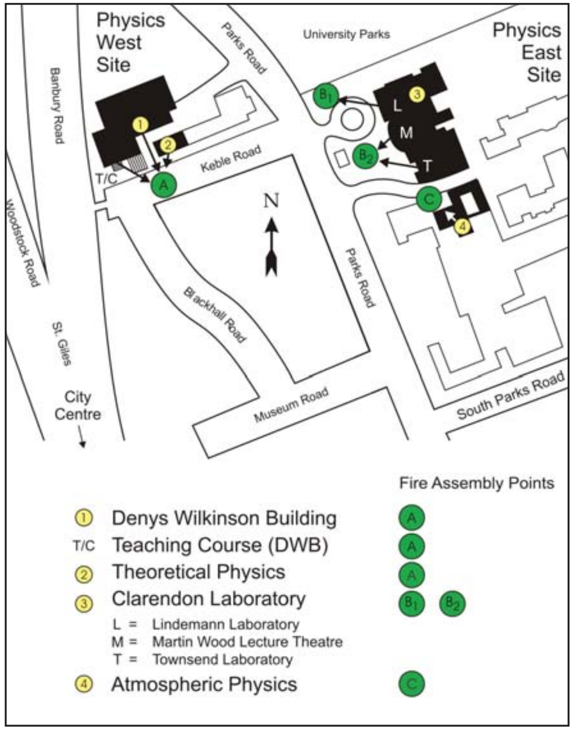
Undergraduate Course Handbook

2011-2012

A view of the Martin Wood Lecture Theatre

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 2010, Hilary Term 2011 and Trinity Term 2011.



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 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 can be found in the Clarendon Laboratory on the Ground Floor.

Contents

Contents Continued

How to use this handbook

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.

At the end of this handbook are appendices giving the syllabuses for the examination papers to be taken in Trinity Term 2012 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.

Syllabuses

Appendix C - Prelims

Appendix D - Part A

Appendix E - Part B

Appendix G - Short Options

Appendix H - Part C

The handbook gives telephone numbers and e-mail addresses for contacting members of the academic staff, 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.

Full details about the Practical Course are given in the *Practical Course Handbook*.

Practical Course

Practical Course Handbook

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 web site www.physics.ox.ac.uk and from the Physics Teaching Faculty in the Clarendon Laboratory.

In this document, Michaelmas Term, Hilary Term, Trinity Term refer to Michaelmas (Winter), Hilary (Spring) and Trinity (Summer) Terms of the academic year, respectively.

Prof Nick Jelley, Head and Chairman of the Physics Teaching Faculty

General Information

www.physics.ox.ac.uk

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 2011. 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 2012 are also subject to possible change and the actual times will be given in the Lecture Database which is published on the physics web site just before the beginning of each term.

Examination Matters

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

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 95 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.

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 Clarendon Laboratory near Reception.

Practical Laboratories

All the undergraduate practical 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. **You will need to use your University card to gain access to all physics buildings.**

Lecture Theatres

The Department is located in four buildings 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 and the Atmospheric Physics building on the east side. 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 main entrance to the Clarendon is on Parks Road, directly opposite the end of Keble Road and next to the University Parks. The Lindemann Lecture Theatre is on the first floor, inside the main entrance to the Clarendon. The Martin Wood Lecture Theatre is in the large new building to the right of the main entrance.

Libraries

Textbooks

Appendix A

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

Oxford University Computer Usage Rules and Etiquette

www.ict.ox.ac.uk/oxford/rules/

There are numerous computer workstations in the teaching laboratories on Level 2 of the DWB. All undergraduates have two separate accounts on the practical course, one for the PC and one for the Mac networks. Students can use the computers at any time during office hours. Students can book practicals as well as use the computers to save and analyse data taken during practicals. 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 regularly (at least once a day during term) check their e-mails.

Refreshments

There are vending machines in the reception area of the practical course 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 practical laboratories or near any computers.**

Data Protection

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

University Policy on Intellectual Property Rights

The University of Oxford has 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

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 http://www.admin.ox.ac.uk/asuc/oxonly/licences/copy.shtml and in **Appendix K.**

Citations and Plagiarism

The University definition of plagiarism can be found at http://www.admin.ox.ac.uk/edc/goodpractice/. Details relating to 'good' academic practice can also be found at http://www.admin.ox.ac.uk/edc/goodpractice/

The University's Regulations state that: *No candidate shall present for an examination as his or her own work any part or the substance of any part of another person's work... passages quoted or closely paraphrased from another person's work must be identified as quotations or paraphrases, and the source of the quoted or paraphrased material must be clearly acknowledged*. (Proctors' and Assessor's Memorandum, Section 9.5 http://www.admin.ox.ac.uk/proctors/pam/index.shtml). "*Turnitin* is a tool that allows papers 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 Computing Service]

Support for Students with Special Needs

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

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. A list of telephone numbers, e-mail addresses and college affiliations is given in **Appendix M**. 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 Support and Guidance

Student health and welfare are primarily College responsibilities: tutors, chaplains, and other confidential advisers make up a sympathetic and effective network of support for students. In addition, the University has a Counselling Service available to help students, and the Student Union has officers working actively to promote student health and welfare. Students are encouraged to refer to http://www.ox.ac.uk/current_students/index.html for further information.

The *Proctors' and Assessor's Memorandum* at http://www.admin.ox.ac.uk/proctors/info/pam/, provides general information on welfare, finance, health and recreation, as well

Data Protection Act

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

Disability website

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

University Policy in Intellectual Property

Appendix K

Copyright Legislation

www.admin.ox.ac.uk/asuc/oxonly/licences/copy.shtmll

Examination Matters

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

Citations and Plagiarism

Communications

E-mail college and other e-mail accounts

Noticeboards

Messenger service

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

www.admin.ox.ac.uk/gso/

www.aspire.ox.ac.uk

Surveys

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

Institute of Physics

www.iop.org/activity/nexus/

as on student conduct and on the running of University examinations. In particular, complaints, appeals and advice on illness during examinations is provided.

Your College tutors provide advice about the Physics courses, and information is also available from the Physics Teaching Faculty in the Clarendon (located near the front entrance) and from the Practical Course in the DWB. Feel free to ask any of the academic staff for help; you can find them in the Department by asking the receptionists in the DWB or the Clarendon, or the secretaries 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.

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. For personal development planning see Aspire at www.aspire.ox.ac.uk.

The Physics Joint Consultative Committee (PJCC)

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

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**. Completion of the on-line feedback is **compulsory** and forms part of your practical requirement. See http://www.physics.ox.ac.uk/pjcc/ 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.

In addition, the "University undertakes University-wide student surveys to provide students with an opportunity to have their say about life at Oxford. Students' views are used by Colleges, Departments, Faculties and the central University services to identify strengths and weaknesses and to put in place changes to help improve the student experience of Oxford." See http://www.admin.ox.ac.uk/ac-div/resources/surveys/ for more information.

Mathematical, Physical and Life Sciences (MPLS) Division

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/teaching-learning/ug-programme/ujcf

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 and membership is currently free for undergraduates. See http://www.iop.org/activity/nexus for more information.

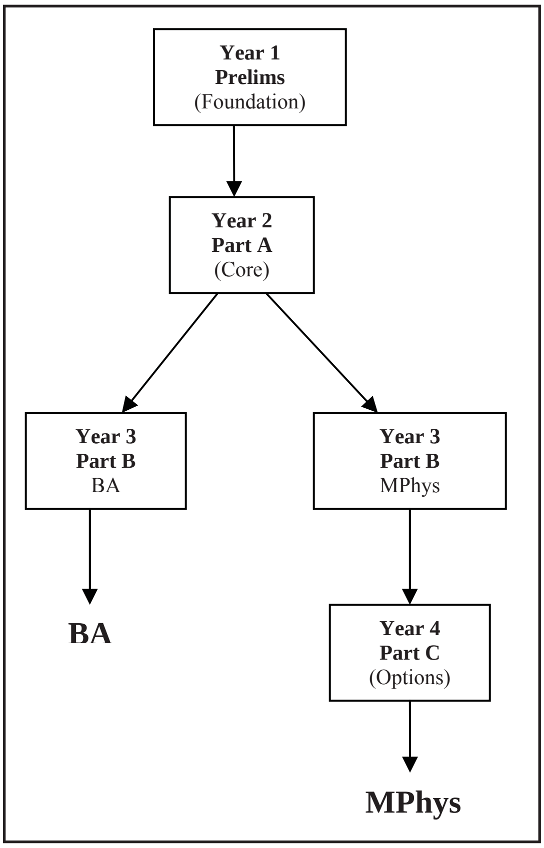
Aims and objectives, teaching and examinations

The Physics Courses – Aims and Objectives

Both the 3-year BA and the 4-year MPhys courses are designed to provide 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 of 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 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/AssuringStandardsAndQuality/subject-guidance/Pages/Subject-benchmark-statements.aspx

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.

Accreditation

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

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 frequently 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 and this is not available to any non-Oxford websites for Copyright reasons.

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 and sent to College tutors.

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 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) 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/.

However some of the lecture materials and lecture lists might also require the physics teaching login details. These are generally in the form

PHYSICSTEACHING\<four letter college code><four randomly assigned numbers>

The password is the same one you use for the PC Network in the teaching labs. Please email support@teaching.physics.ox.ac.uk, explaining what you are trying to do, if you forget your 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 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 with 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.

Class I: the candidate shows excellent problem-solving skills and excellent knowledge of the material, and is able to use that knowledge in unfamiliar contexts;
Class II.1: the candidate shows good problem-solving skills and good knowledge of the material;
Class II.2: the candidate shows basic problem-solving skills and adequate knowledge of most of the material;
Class III: the candidate shows some problem-solving skills and adequate knowledge of at least part of the material;
Pass: the candidate has made a meaningful attempt of at least one question.
For the BA degree FHS Parts A and B are approximately weighted, 43% : 57% and for the MPhys FHS Parts A, B, C are approximately weighted 24% : 34% : 42%.

Final Degree Classes are assigned on the basis of a careful consideration of the total numerical mark with the project and practical 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 are encouraged to 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 or written skills exercise and an assessed practical. The total marks are made up as follows:

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

The first **15** marks 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.

(i) 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.

(ii) Part B: Written Skills

In the third year both BA and MPhys students will write up one practical experiment, called Written Skills. The report will first be marked informally by your tutors. Students will revise the report taking into account the tutor’s comments and the revised version will then be marked by your tutor. Each College will make arrange with their students when they will need to hand in their written skills reports. Tutors must give the examiners the mark by 6th week of Trinity Term at the latest.

If you are a BA student who has chosen to do 6 days of practical work, you will have to do one written skills report based on the experiment you have carried out on your own in the third year. BA students substituting practical work will not be required to do written skills. A numeric mark for the work substituted will instead be given to the Examiners.

MPhys students will do one written skills report based on the experiment they carried out on their own in the third year.

(iii) Part A and Part B: Assessed Practical

In both the 2nd and 3rd years there is one practical, called an Assessed Practical, that is marked by a senior demonstrator.

Marking Scheme for Oral and Written Skills

- A mark of 15: Students can attract the top mark for exceptional performance for their oral presentation (talk) in college or for their written skills report.
- A mark of 12: Students will attract this mark if the oral presentation or written skills report is regarded as very good.
- A mark of 10: Students will be awarded this mark if the presentation or written skills report was acceptable and average in quality.
- A mark of 9 or below: Students will be awarded this mark if the presentation or written skills report 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 or written skills report should achieve 10 marks. Students who put in little or no effort can score very low marks. More details can be found in the *Practical Course Handbook.*

Marking of the Assessed Practical

The assessed practical is chosen at random **in advance** from the student's logbook and marked by a senior demonstrator. The marks 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.

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.

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; however, to avoid having to apply for additional Local Authority (LA) funding at a later stage, 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.

Three or Four year course

Students who are eligible to proceed to the MPhys course, but are unsure of whether they want to do the MPhys course should talk to their College tutors. The Examination entry for the third year is at the end of 4th week of Hilary Term and **this is the latest time for changing your course from the BA to the MPhys or vice versa** (without incurring a fee). More information can be found at http://www.ox.ac.uk/current_students/index.html. (See also 'Changing from the MPhys to the BA' on page 21.)

Examination Preparation

There are a number of resources available to help you including 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

The Examiners are responsible for the detailed weightings of papers and projects. The precise details of how the final mark is calculated is published on the Examination matters webpage at www.physics.ox.ac.uk/teach/exammatters.htm. Students are notified by e-mail when they become available.

Examination Dates

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

Examination Regulations

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

Weightings of Papers

After Part B of the BA or Part C of the MPhys, candidates will be ranked on the basis of a total mark that is obtained by adding the scaled marks of individual elements multiplied by the following weightings:

BA

Each Part A paper (3)	0.75
Part A Short Option	0.375
Part A full Practicals*	0.75
Each Part B paper (4)	0.625
Part B Short Option	0.50
Part B Practicals or second short option	0.50
BA Project	0.75

*Part A half practicals 0.375 plus second short option 0.375

MPhys

Each Part A paper (3)	0.70
Part A Short Option	0.35
Part A Practicals*	0.70
Each Part B paper (3)	1.00
Part B Short Option	0.50
Part B Practicals**	1.00
Each Part C Major Option (2)	1.50
MPhys Project	1.75

*Part A half practicals 0.35 plus second short option 0.35
**Part B half practicals 0.5 plus second short option 0.5

This table gives the intended relations between percentage marks and FHS class.

Mark	>70	60-70	50-60	40-50	30-40	<30
Class	I	II.1	II.2	III	Pass	Fail

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/. Please note that only results from 2007/08 onwards will be available.' [Ref.: A guide to completing online registration & accessing Student Self Service at Oxford]. Marks for all components are given, from 2010 onward, as percentages; e.g. 40 marks for Part A full practicals is entered as 80.

Prizes

A number of prizes are awarded annually for excellence in various aspects of the BA and MPhys final examinations:

- 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 best use of experimental apparatus in the MPhys
- 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 best project and report
- A Gibbs Prize for the best performance in the Physics Department Speaking Competition (held in the 2nd year, see page 16).

Past Exam Papers and Examiners' Reports

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

Physics and Philosophy

There is a corresponding Handbook for this course: *Physics and Philosophy Course Handbook*. 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 the Chair, Dr Chris Timpson(christopher.timpson@bnc.ox.ac.uk) or Secretary, Dr Christopher Palmer(c.palmer@physics.ox.ac.uk).

Physics and Philosophy is normally a 4 year course. The first year of the course leads to the examination called Moderations, which consists of five papers, three in mathematics and physics and two in philosophy. After successfully completing Moderations, 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 (BT: VII. 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, of which the following is an abbreviated description. For either Parts A and B taken together, or for Parts A, B and C taken together, a net Physics mark *M* and Philosophy mark *P* are constructed, each on a scale from 0 to 100, and a combined mark *U*, weighted according to the total weight of papers in each subject (The weights of individual papers are given below in the sections where they are described). No candidate will be given a classification lower than that implied by the value of *U* as follows: 70-100 First; 60-69 Upper Second; 50-59 Lower Second; 40-49 Third; 30-39 Pass; 0-29 Fail. However a candidate who achieves a value of *U* above 67 (or 57) will be awarded a First (or Upper Second) provided their net mark in whichever is the preponderant subject in Part C is of the higher classification, and in the other subject is not more than one class division lower. The award of a Third, Pass or Fail will always be by individual consideration.

Students should note that they will have to complete, as part of their Part A requirements, three particular 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 or viewing the Safety Lecture is compulsory.

Summary of Examination Requirements

Physics	**Physics and Philosophy**
Prelims Four 2½-hour Compulsory Papers CP1, CP2, CP3, CP4 Short Option Paper Satisfactory Practical Work	**Mods** Three Physics Papers CP1, CP3, CP4 Two Philosophy Papers
Part A Three 3-hour Compulsory Papers A1, A2, A3 Short Option Paper [1½ hour per option] Part A Practical Work	**Part A** Three Physics Papers A1, A2P, A3 Satisfactory Practical Work
Part B **BA** (3 year Course) Four [1½ hour] including Section III, IV, VI and one other, from B1, B2 and B3 Short Option Paper [1½ hour per option] Part B Practical Work BA Project Report **Part B** **MPhys** (4 year Course) Three 3-hour Papers: B1, B2, B3 *Each 3-hour B paper will be presented as two individual papers. The examination at the end of Trinity Term will consist of six 1½ hour papers.* Short Option Paper [1½ hour per option] 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 3-hour 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 2011-2012

Induction

All Physics and Physics and Philosophy first years are **required** to attend Induction from 2.15 - 4.15 pm on Friday afternoon of 0th 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, and you will be given your copy of the *Practical Course Handbook*.

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).

Group A (Practicals usually on Thursdays)

Balliol, Brasenose, Exeter, Jesus, Magdalen, Mansfield, Merton, Queen's, 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 is some reassignment to even out numbers.)

Safety Lecture

A safety lecture, which is **compulsory** for all Physics students is held on the Monday of 1st week of Michaelmas Term at 2.00 pm in the Martin Wood lecture theatre. Only those who have attended are allowed to work on the Practical Course. You will be asked to sign a safety declaration.

If for any reason it is not going to be possible for you to attend, tell your tutor, and let Dr Karen Aplin (k.aplin1@physics.ox.ac.uk) know before the beginning of 1st 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. During Michaelmas Term weeks 3 - 8 you will also be assigned to a further 3 hour session in the computing laboratory - 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 unpreared may be asked to leave.

There will be an important meeting on Monday of 1st week at 12.00 noon in the Martin Wood Lecture Theatre, at which essential administrative arrangements will be announced. Pairings for practical work will be registered at the Practical Administration session immediately following 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.

Self-study modules in basic mathematics and mechanics

These are designed to bridge the gap between school and university maths and mechanics for those who need it. Your tutor has more information, and they will be explained at Induction. See also '*The Language of Physics*' J. P. Cullerne and A. Machacek (Oxford).

Dates at a glance

Induction
7 October 2011
at 2.15 pm

Essential Administration
10 October 2011
at 12.00 noon

Safety Lecture and Practical Administration
10 October 2011
at 2.00 pm

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 2½ hour papers [CP1: Physics 1, CP2: Physics 2, CP3: Mathematical Methods 1 and CP4: Mathematical Methods 2], a Short Option (1½ hour paper) 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 15 'days' - 11 laboratory experiments plus 4 days computing assignments. 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, and the "Physics Today" lectures cover exciting aspects of Contemporary Physics.

Exam 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* 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 first year course leads to the examination called "Moderations", 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 Moderations, 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/).

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 four lectures.

Lecture timetables

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

Michaelmas Term: week by week

1	2	3	4	5	6	7	8	No. of lectures
[CP1: Mechanics --------------------------]								8
			[CP1: Special Relativity ------------------------------]					10
				[CP2 :Circuit Theory ---------------------]				10
[CP2: Optics ------------------]								6
[CP3: Vectors and Matrices --]								18
		[CP3: ODEs and Complex Numbers -----------]						10
[CP4: Calculus --------------------------]								11
[Physics Today & Extras --]								14

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
[CP3: V&M-----------]								2
[CP4: Multiple Int/Vector Calc ---------------------]								14
[CP4:Normal Modes and Wave Motion ------------------------]								12
[Extras---]								4

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 2011-2012

Introduction to 2nd year
10 October 2011

Part A Papers

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

Short Options
see page 28

Physics Speaking Competition

Teaching and Learning Physics in Schools

20 October 2011

Undergraduate Physics Conference

www.physics.ox.ac.uk/users/palmerc/oupc.htm

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 3 hour 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 http://www.physics.ox.ac.uk/teach/exammatters.htm will contain details of the handling of logbooks.

During Hilary Term, second year students give short talks within Colleges, as training in oral communication skills. 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). 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 http://www.physics.ox.ac.uk/teach/OxOnly/OralSkills/ to give students an idea of what a good oral skills 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 10 am in the Lindemann Theatre on Thursday 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. See page ? for more details,

This course is not available for Physics and Philosophy students.

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 Colleges, with bookings being taken from mid-Michaelmas Term. For more details see www.physics.ox.ac.uk/users/palmerc/oupc.htm.

Exam 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* 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

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**). Please note the advice given in the *Physics and Philosophy Course Handbook* concerning 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 as ¾ for A1 and A3 and ½ for A2P.

For the experimental requirements in Physics and Philosophy Finals Part A, three physics practicals **must** be completed by the end of your second year. The three practicals are: "Free and bound electrons" (practical GP14 in the *Physics Practical Course Handbook*), "Michelson interferometer" (Practical OP02) and "Stern-Gerlach effect" (Practical OP15). See the *Practical Course Handbook* section 1.5 for more details.

During Hilary Term, students give short talks within Colleges, as training in oral communication skills. 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).

You have to attend the 1st year 'Introduction to Practicals' and the Safety Lecture at the beginning of your **second** year, see page 16. Only students who are recorded as having attended the Safety Lecture are allowed to work on the Practical Course.

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 four lectures.

Michaelmas Term: week by week

Part A Papers

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

1	2	3	4	5	6	7	8	No. of lectures
[A1: Statistical and Thermal Physics --]								22
				[A2: Electromagnetism -------------------]				11
					[A3: Quantum Mechanics ----]			5
[S20: History of Science --]								12
[Probability and Statistics ------]								6
[Mathematical Methods & Extras ---]								20

Hilary Term: week by week

Part A Papers

A1: Thermal Physics

A2: Electromagnetism and Optics

A3: Quantum Physics

S07: Classical Mechanics

1	2	3	4	5	6	7	8	No. of lectures
[A1: Statistical and Thermal Physics ---------------]								12
[A2: Electromagnetism ---------------]								8
			[A2: Optics ---]					13
[A3: Quantum Mechanics --------------]								12
				[A3: Further Quantum Physics ----------]				12
[S07:Classical Mechanics ---]								12
[S21: Philosophy of Science ---]								12

Trinity Term: week by week

Papers A2 and A3

Short Options

1	2	3	4	5	6	7	8	No. of lectures
[A2: Optics ----------]								4
[A3: FQP ------------------------]								9
[S01: Functions of a Complex Variable]								12
[S02: Astrophysics ----------------------]								12
[S04: Energy Studies ---------------------------------]								12
[S09: Financial Physics --------------------]								12
[S12: Introduction to Biological Physics -----------]								12
[S25: Physics of Climate Change ---------]								12

Third Year 2011-2012 [BA Course]

Choice of Course

During Michaelmas, you must decide whether you will take the three year course (BA) or the four year course (MPhys). If you have any doubts concerning which course you should take you should discuss the situation carefully with your tutor. For the BA approximately 57% of the marks for your final degree classification depend on work done for Part B.

Part B Examination

The examination will take place at the end of Trinity and consists of four 1½ hour papers, a Short Option paper, assessed practical work and a report on a project or extended report. The four 1½ hour papers are chosen from the B papers of the 3rd year of the MPhys course: B1: *I. Flows, Fluctuations and Complexity* and *II. Symmetry and Relativity*; B2: *III. Quantum, Atomic and Molecular Physics* and *IV. Sub-Atomic Physics*; B3: *V. General Relativity and Cosmology* and *VI. Condensed-Matter Physics* ***and*** **must** include *III, IV* and *VI.* Students will be required to answer two questions from a total of four.

The B papers will be divided into two sections; each 1½ hours duration with students being required to answer two questions from four in each section. 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 Written Skills

The requirement for practical work for Part B is 6 days, undertaken in Michaelmas and Trinity. A second Short Option may be offered in place of practical work. There is no practical work in Hilary. BA students have to write a report on the practical they have done on their own in the third year. The BA project is undertaken in the second half of Hilary Term. The practical report write-up is part of the training in written communication skills for in Part B. There is also an assessed practical, see page 9 of the *Practical Course Handbook* and the examiners' matters web page will contain details of the handling of logbooks.

Group Project

At the beginning of Michaelmas Term all BA students will be arranged into groups of 5-6 people with the task of preparing a presentation in weeks 7 or 8 . There may be a prize for best presentation. More details will be announced at the introductory lecture.

Short Options & Language Option

Details on the Short Options (and alternatives) are given on page 28. It is possible to offer a second Short Option in place of 6 days of practical work, but note that most short option lectures are delivered at the start of Trinity Term.

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.

BA Project

The project is either a laboratory or a literature project and undertaken during the final four weeks of Hilary. The *BA Projects Handbook* contains details of both types of projects and will be circulated at the start of Michaelmas. This contains the timetable for carrying out the project work and handing in the report. You must specify your choice of project or report by noon on Friday of 2nd week of Michaelmas. The allocation of projects will be published during 5th week of Michaelmas, and you should then contact your supervisor to discuss preparation for the project work. **There is a compulsory Safety Lecture in 8th week of Michaelmas, which all BA project students MUST attend.** 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.

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 which students may apply to their College, for attendance with bookings being taken from mid-Michaelmas Term. For more details see www.physics.ox.ac.uk/users/palmerc/oupc.htm.

Introduction to 3rd year
10 October 2011

BA Project or Essay
BA Projects Handbook 2011-2012

Part B Papers
B1: I. Flows, Fluctuations and Complexity and II. Symmetry and Relativity
B2: III. Quantum, Atomic and Molecular Physics and IV. Sub-Atomic Physics
B3: V. General Relativity and Cosmology and VI. Condensed-Matter Physics

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

Part B Practical

Exam Entry

Entry for the 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* 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.

Third Year 2011-2012 [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 Part A the examiners will have published a list of those students eligible to proceed to the MPhys course; the standard required is the equivalent of a II.1 Class or better in Part A. You should bear in mind that the four year course is designed to be a challenging one and will involve an appreciable amount of advanced work. You will also be expected to work more independently than during your first three years. If you take the four year course, 42% of the total marks leading to your final degree classification will depend on work done in the 4th year.

Introduction to 3rd year
10 October 2011

Part B Examination

The examination will take place at the end of Trinity Term and consist of three 3 hour papers: B1: *I. Flows, Fluctuations and Complexity* and *II. Symmetry and Relativity,* B2: *III. Quantum, Atomic and Molecular Physics* and *IV. Sub-Atomic Physics,* B3: *V. General Relativity and Cosmology* and *VI. Condensed-Matter Physics*. **Each 3 hour B paper will be presented as two individual papers. The examination at the end of Trinity Term will consist of six 1½ hour papers. Students will be required to answer two questions from a total of four on each of these papers.**

Part B Papers

B1: I. Flows, Fluctuations and Complexity and II. Symmetry and Relativity

B2: III. Quantum, Atomic and Molecular Physics and IV. Sub-Atomic Physics

B3: V. General Relativity and Cosmology and VI. 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 Written Skills

Part B Practical

The requirement for practical work for Part B is 10 days (usually 6 days in Michaelmas and 4 days in Trinity), The solo practical takes place in weeks 3-6 of Michaelmas Term.. It is possible to substitute 6 days of practical work, by taking a second short option, but a minimum of 6 days must be offered. There is also an assessed practical, see page 9.

There is no practical work in Hilary but students should write a report on the one practical they have done on their own. The practical report write-up is part of the training in written communication skills and contributes to Written Skills in Part B.

The *Practical Course Handbook* and http://www.physics.ox.ac.uk/teach/exammatters.htm will contain details of the handling of logbooks.

Short Options & Language Option

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.

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

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 27.

Major Options

Changing from the MPhys to the BA

If you are considering changing from the MPhys to the BA, you must make an application to your College.

If you decide to change to the BA after you have entered for the MPhys Part B (4th week of Hilary Term), you will have to formally withdraw from the MPhys degree course via College and re-enter to do the BA course.

If you decide to change to the BA after you have had the outcome of your Part B results, you will have to formally withdraw from the MPhys degree course via College and re-enter to do the BA course. For completion of the BA course, it will be necessary for you to complete a BA project. This can be done during the summer vacation, subject to availability of supervisors, or in the next academic year. It is important to note that you will only graduate at the end of the next academic year.

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

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 mid-Michaelmas Term. For more details see www.physics.ox.ac.uk/users/palmerc/oupc.htm.

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 via the Assistant Head of Teaching (Academic) in Trinity Term of your third year.

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

- B1:I. Fluctuations, flows and complexity
- B1:II. Symmetry and relativity
- B2:III. Quantum, atomic and molecular physics
- B2:IV. Sub-atomic physics
- B3:V. General Relativity and cosmology
- B3:VI. Condensed-matter physics
- BT: VII. Classical mechanics

Your selection must include at least two of the subjects II, V and VII.
Subjects I-VI are the same as the core Part B physics papers taken by MPhys students, which are examined in three three-hour papers, B1, B2 and B3 as shown above, with 1½ hours allocated to each of the two sections in each paper. The syllabus and lectures for subject VII Classical Mechanics are identical with the those for the Physics Short Option S07 of the same name, but the paper is not the same. The BT paper is specially set for PP students, in the same format as the other six subjects in Part B, and 1½ hours in length.

The weights assigned to the Part B papers in the Finals algorithm are 1 for each 3-hour Philosophy paper and ½ for each 1½-hour physics paper.

Third Year Outline of Topics

Lecture timetables

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

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. There are normally 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 four lectures.

Part B Papers

B1: I. Flows, Fluctuations and Complexity and II. Symmetry and Relativity

B2: III. Quantum, Atomic and Molecular Physics and IV. Sub-Atomic Physics

B3: V. General Relativity and Cosmology and VI. Condensed-Matter Physics

S18: Advanced Quantum Mechanics

S07: Classical Mechanics

BA Projects

Michaelmas Term: week by week

Weeks 1 2 3 4 5 6 7 8	No. of lectures
[B1: I. Flows, Fluctuations and Complexity ---]	22
[B1:II. Symmetry and Relativity --]	22
[B2: III. Quantum, Atomic and Molecular Physics ----------------------------------]	22
[S20: History of Science --]	12
[Extras ---]	2

Hilary Term: week by week

Weeks 1 2 3 4 5 6 7 8	No. of lectures
[B2: IV. Sub-Atomic Physics ---]	22
[B3: V. General Relativity and Cosmology --]	22
[B3: VI. Condensed-Matter Physics ---]	22
[S07:Classical Mechanics --]	12
(from week 4) [S18:Advanced Quantum Mechanics ---------------]	12
[S21: Philosophy of Science --]	12
[Extras---]	1

Part B Papers

Part B Practical

Short Options

Trinity Term: week by week

Weeks 1 2 3 4 5 6 7 8	No. of lectures
[B1: I. Flows, Fluctuations and Complexity]	2
[B1:II. Symmetry and Relativity ----------]	2
[B2: III. Quantum, Atomic and Molecular Physics]	2
[B2: IV. Sub-Atomic Physics ---------------]	2
[B3: V. General Relativity and Cosmology -------]	2
[B3: VI. Condensed-Matter Physics ------]	2
[S04: Energy Studies ---------------------------------]	12
[S09: Financial Physics --------------------]	12
[S12: Introduction to Biological Physics -----------]	12
[S16: Plasma Physics -----------------------]	12
[S19: Particle Accelerator Science -------]	12
[S25: Physics of Climate Change ---------]	12
[S26: Stars and Galaxies ------------------]	12

Major Options
2 Major Options

Alternative Major Options

MPhys Projects
MPhys Projects Handbook 2011-2012

Part C Finals for the 4-year MPhys

In Trinity Term 2012, you are required to take two 3 hour examination papers on Major Options 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.

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).

Lectures and Classes for the Major Options

The lectures for the Major Options take place from the start of Michaelmas Term until the middle of Trinity Term. During Hilary Term, fewer lectures are given to allow time for the MPhys project.

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: 4 classes in Michaelmas, 2 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

Each of the seven physics Major Options are examined in a single 3-hour paper. Answer 4 questions from a choice of 8.

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 c.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 Hilary Term. **There is a compulsory Safety Lecture in 8th week of Michaelmas Term, which all MPhys students must attend.** The *MPhys Projects Handbook* containing details of the projects for the MPhys will be circulated at the start of Michaelmas Term. This also contains a timetable for carrying out the project work and handing in the report. You must specify your choice of project by noon on Friday of 2nd week, Michaelmas Term. The allocation of projects will be published in 5th week. **Before the end of Michaelmas Term** students must 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 Projects Handbook* 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

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 Projects Handbook 2011-2012*. Syllabuses for the Physics Major Options are given in **Appendix G**.

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 8th week of Michaelmas Term if you intend to do an experimental project.**

Fourth Year Outline of Topics

Lecture timetables

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

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. Each physics Major Option is usually supported by 8 classes. Typically a class size is 8 students.

Michaelmas Term: week by week

Part C Papers

Weeks 1–8	No. of lectures
[C1: Astrophysics ---] (weeks 1–8)	28
[C2: Lasers and Quantum Information Processing ---] (weeks 1–8)	24
[C3: Condensed Matter Physics ---] (weeks 1–8)	24
[C4: Particle Physics ---] (weeks 1–8)	24
[C5: Physics of Atmospheres and Oceans ---] (weeks 1–8)	24
[C6: Theoretical Physics ---] (weeks 1–8)	24
[C7: Biological Physics ---] (weeks 1–8)	24
[Extras ---] (weeks 1–8)	1

Hilary Term: week by week

Part C Papers

MPhys Projects

Weeks 1–8	No. of lectures
[C1: Astrophysics ---] (weeks 1–8)	9
[C2: Lasers and Quantum Information Processing ---] (weeks 1–8)	6
[C3: Condensed Matter Physics ---] (weeks 1–8)	6
[C4: Particle Physics ---] (weeks 1–8)	9
[C5: Physics of Atmospheres and Oceans ---] (weeks 1–8)	8
[C6: Theoretical Physics ---] (weeks 1–8)	18
[C7: Biological Physics ---] (weeks 1–8)	8
[Extras ---] (weeks 1–8)	1

Trinity Term: week by week

Part C Papers

Weeks 1–8	No. of lectures
[C1: Astrophysics ---] (weeks 1–4)	8
[C2: LS &QIP ---] (weeks 1–4)	9
[C3: Condensed Matter Physics ---] (weeks 1–4)	13
[C4: Particle Physics ---] (weeks 1–4)	8
[C5: AOPP ---] (weeks 1–4)	10
[C6: Theoretical Physics ---] (weeks 1–4)	0
[C7: Biological Physics ---] (weeks 1–4)	8

Short Options 2011-2012, Language Option & Alternatives

The Short Options for the academic year 2011/12 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). Short options will be offered in alternate years and this will come 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**.

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)	TT
S03	Quantum Ideas	1 only	(a)	TT
S04	Energy Studies	2 3	(c)	TT
S07	Classical Mechanics	2 3	(a), (d)	HT
S09	Financial Physics	2 3	(b)	TT
S12	Introduction to Biological Physics	2 3	(c)	TT
S16	Plasma Physics	3	(g)	TT
S18	Advanced Quantum Mechanics	3	(a)	HT
S19	Particle Accelerator Science	3	(g)	TT
S25	Physics of Climate Change	2 3	(b)	TT
S26	Stars and Galaxies	3	(a)	TT

From other Departments or Faculties

Code	Title	Years	Notes	Term
S20	History of Science	2 3	(e)	MT
S21	Philosophy of Science	2 3	(e)	HT
S22	Language Option (French and Spanish or German)	2 3	(f)	TT
S27	Philosophy of Space-Time	2 3	(e)	
S28	Philosophy of Quantum Mechanics	2 3	(e)	

Note:

(a) This Short Option offered every year

(b) This Short Option will be offered in Trinity 2013 not in 2014.

(c) This Short Option will be offered in Trinity 2014 not in 2013.

(d) Physics and Philosophy Paper BT: VII. *Classical Mechanics.*

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

(f) Subject to passing the preliminary test in Hilary Term

(g) This Short Option will be offered in Trinity 2013.

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.

Format of the Short Option Paper

Physics 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 **four questions**, two from each section, in 3 hours.

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 c.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.

Pre-approved subjects

Philosophy of Science is a short option which is offered by the Faculty of Philosophy and has been pre-approved. The short option, History of Science, offered by the Faculty of History has also been pre-approved. This means that students wishing to do these two separate short options do not have to seek permission from the Head of the Physics Teaching Faculty.

Please note: for students doing both short options Philosophy Science and History of Science, this becomes the Supplementary Subject: History and Philosophy of Science.

Supplementary Subject: History and Philosophy of Science

A Supplementary Subject is a paper offered within the University by other departments. Physics students may substitute such a paper instead of two short options.

Anyone wishing to enrol for this Supplementary Subject should come to the first lecture, to be given in the Tanner Room, Linacre College, see the Physics Department's *Lecture Database* (www.physics.ox.ac.uk/lectures/). It is especially important to be present at the first lecture, immediately after which tutorial groups for the term will be arranged. 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 supplementary subject, please inform the Assistant Head of Teaching (Academic) by e-mail at c.leonard-mcintyre@physics.ox.ac.uk by 2nd week of Michaelmas Term.

The examination dates for these short options is different from the normal Physics Short Option date. No examination results will be released before the completion of all the Physics examinations.

Alternative Subject

Application must be made via the Assistant Head of Teaching (Academic) by e-mail to c.leonard-mcintyre@physics.ox.ac.uk to 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 examination already exist within the University and is considered appropriate. Students will be advised of the decision by the end of 8th week of Michaelmas Term.

Language Option

The language option will involve 32 hours of classes together with associated work in Trinity Term. It can be used to replace the Short Option paper in either Part A or Part B. It may not be taken in both Parts A and B.

A course is offered in French every year. Courses in German or Spanish are offered in alternate years. In Trinity Term 2012, 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 to the Head of the Physics 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).

Extra practical and an extended practical

There are two options for students wishing to replace a Short Option with practical work. Extra practical is 6 days of extra practical work in addition to the normal practical quota for the second and third year. An extended practical is very like a 'mini project'

Students must apply, by email to the Assistant Head of Teaching (Academic) at c.leonard-mcintyre@physics.ox.ac.uk to replace a Short Option paper in Part A or Part B by extra practical work or an extended practical. The application must be made before noon on Friday of 2nd week of Michaelmas Term.

For both the extended prcatical and extra practial students will have to produce a report on the work they have done.

The report must be submitted in paper copy **and** an electronic copy on a CD. No tutor input for this report will be allowed. Students must submit their Written Report to the Physics Teaching Faculty Office, **NOT** the Examination Schools, before noon on Friday of 5th week of Trinity Term.

Extra practical

The 6 (six) extra days practical work will begin only when the normal practical quota has been completed and should be booked and grades entered on the MS (Management Scheme) as usual.

For Part B MPhys students, the write up for the extra practical work will not be the same as that for Written Skills.

Part A students doing the 6 additional days of practical in Part A will not be allowed to repeat this option for Part B of their course.

Extended practical

The extended practical is in essence a mini project and would usually be an extension of one of the practicals done in the second or third year.

Assessment of extra practicals and extended practicals

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

Note will be taken of good argument in the analysis, the use of English/Style and, where appropriate clear diagrams/plots and references

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 10am in the Lindemann Theatre on Thursday 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. The option replaces eight (8) days of practicals. 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.

N.B. It is **NOT** possible to substitute for all practical work in Part A by doing **BOTH** an extra short option **AND** the Teaching Physics in Schools option. 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* 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.

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)

S04: Energy Studies

'Energy Science', John Andrews and Nick Jelley (OUP 2007)**
'Renewable Energy Resources', Twidell & Weir (E&FN Spon)
'Energy', Aubrecht (Prentice Hall)
'Nuclear Energy', Bodarsky (AIP Press)
'Renewable Energy, Power for a Sustainable Future', Boyle (Editor) (OUP/Open University)
'Engineering Thermodynamics', Rogers & Mayhew (Longman)
'Environmental Physics', E Boeker & R van Grondelle
'Nuclear Reactor Engineering', S Glasstone & A Sesonske
'Energy', a guide book, J Ramage
'Sustainable Energy - Without the Hot Air' David JC Mackay
http://www.withouthotair.com

S09: Financial Physics

'Financial Market Complexity', Neil F. Johnson, Paul Jefferies , Pak Ming Hui (OUP, 2003)

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', 3rd edition, L.I.Schiff, (McGraw-Hill)
Useful as a reference text both for scattering theory and the Dirac equation.
'Quantum Mechanics', Volume II, C. Cohen-Tannoudgi, B. Diu and F.Laloe, (John Wiley & Sons)
A very readable introduction to scattering theory although somewhat limited in content.
'Modern Quantum Mechanics', J.J. Sakurai, (Addison-Wesley)
Contains an excellent treatment of the scattering theory topics of the course.
'Relativistic Quantum Mechanics', I.J.R. Aitchison, (Macmillan)
An excellent introduction to the relativistic aspects of the course.
'Relativistic Quantum Mechanics', Bjorken and Drell, (McGraw-Hill) A "classic" text.

S19: Particle Accelerator Science

'An introduction to particle accelerators', Edmund Wilson, (Clarendon Press, 2001), QC787.P3 WIL, ISBN-10: 0198508298, ISBN-13: 978-0198508298 **
'The physics of Particle accelerators', Klaus Wille, QC787.P3 WIL ISBN 0198505493 *
More advanced:
'Handbook of Accelerator Physics and Engineering', Alex Chao and Maury Tigner, ISBN: 9810235003 *

S25: Physics of Climate Change

'Global Warming: Understanding the Forecast', David Archer(Blackwell, 2007) ISBN: 978-1-4051-4039-3
'Climate Change 2007: The Physical Science Basis', S. Solomon, D. Qin et al (eds.)(CUP, 2007) ISBN: 978-0-521-70596-7, available online at http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html
"An Introduction to Atmospheric Physics" (2nd edition), D. G. Andrews, CUP, 2010, Chapter 8

S26: Stars and Galaxies

"Astrophysics for Physicists", Chouduri
"Galactic Dynamics", Binney & Tremaine
"Stellar Structure and Evolution", Kippenhahn & Weigert
WIL ISBN 0198505493 *
More advanced:
'Handbook of Accelerator Physics and Engineering', Alex Chao and Maury Tigner, ISBN: 9810235003 *

First Year

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

Textbooks based on the Oxford course in its various incarnations:
‘Concepts in Thermal Physics,’ S. J. Blundell and K. M. Blundell (2nd edition, OUP 2009) **
‘Statistical Mechanics: A Survival Guide,’ A. M. Glazer and J. S. Wark (OUP 2009)
‘Lectures on Statistical Mechanics,’ M. G. Bowler (Pergamon 1982)

More undergraduate textbooks (from Berkeley, Cambridge, Manchester):
'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)

A more advanced-level modern course (from MIT):
'Statistical Physics of Particles,' M. Kardar (CUP 2007)

Classical books – from basic to advanced, in (approximate) order of increasing level:
Feynmann Lectures on Physics, Volume I (Basic Books 2011)
'Thermodynamics,' E. Fermi (Dover 1956)
'Thermodynamics and the Kinetic Theory of Gases,' W. Pauli (Volume 3 of Pauli Lectures on Physics, Dover 2003) *
'Statistical Mechanics,' W. Pauli (Volume 4 of Pauli Lectures on Physics, Dover 2003) *
'Statistical Physics, Part I,' L. D. Landau and E. M. Lifshitz (3rd edition, Volume 5 of Landau and Lifshitz Course of Theoretical Physics, Butterworth-Heinemann, 2000) *
'Physical Kinetics,' E. M. Lifshitz and L. P. Pitaevskii (Volume 10 of Landau and Lifshitz Course of Theoretical Physics, Butterworth-Heinemann, 1999)
'Statistical Thermodynamics,' E. Schroedinger (Dover 1989)

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, 3rd ed(Addison-Wesley, 1998) **
'Optics', M V Klein & T E Furtak, 2nd ed (Wiley, 1986)
'Light', R W Ditchburn, 3rd ed, (Academic Press, 1976)
'Optics and Photonics', F G Smith and T A King (Wiley, 2000)
'Optics', W T Welford, 3rd ed (OUP, 1988)
'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) 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.

Third Year

B1: I. Flows, Fluctuations and Complexity, and II. Symmetry and Relativity

I. Flows, fluctuations and complexity

'Physical Fluid Dynamics', 2nd edition, D J Tritton, (CUP) 1988, ISBN-10: 0198544936**
'Elementary Fluid Dynamics', D J Acheson, (OUP) 1990, ISBN-10: 0198596790 *
'Fluid Dynamics for Physicists', F E Faber, (CUP) 1995, ISBN-10: 0521429692 *
'Non-linear 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).

II. Symmetry & 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

B2: III. Quantum, Atomic and Molecular Physics, and IV. Sub-Atomic Physics

III. 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

IV. 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)

B3: V. General Relativity and Cosmology, and VI. Condensed-Matter Physics

V. 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)

VI. Condensed Matter Physics

'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 Computing: A Short Course from Theory to Experiment', Joachim Stolze and Dieter Suter (Wiley 2004) **
'Quantum Computation and Quantum Information', Michael A. Nielsen and Isaac L. Chuang (Cambridge 2000)*
'Feynman Lectures on Computation', Richard P. Feynman, Anthony J. G. Hey, Robin W. Allen (Penguin 1999)
'The Physics of Quantum Information', Dirk Bouwmeester, Artur Ekert and Anton Zeilinger (Springer 2001)
'Lasers and Electro-Optics: Fundamentals and Engineering', Christopher C. Davies, (Cambridge University Press, First published 1996. Reprinted with corrections 2000, 2002) **
'Modern Classical Optics', G. Brooker, (OUP 2003) *
'Laser Electronics', Joseph T. Verdeyen, (Prentice-Hall, 3rd ed. 1995)
'Quantum Electronics', A.Yariv, (Wiley, 3rd ed. 1989) OR 'Optical Electronics in Modern Communications', A.Yariv (OUP 1997)
'Fundamentals of Photonics', B.E.A. Saleh & M.C. Tech (Wiley 1991)
'Principles of Lasers,' Orazio Svelto, (Plenum Publishing Corporation KLUWER ACADEMIC PUBL)
ISBN10: 0306457482, ISBN13: 9780306457487
"Laser Physics" Hooker and Webb, ISBN13: 9780198506911, ISBN10: 0198506910

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, 8^{th} 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

'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 *
'An Introduction to Dynamic Meteorology', 4th edition, J R Holton, (AP) 2004, ISBN-10: 0123540151 *
'Atmospheric Science, An Introductory Survey', 2nd edition, J M Wallace and P V Hobbs, (AP) 2006, ISBN-10: 012732951X*
'An Introduction to Atmospheric Radiation', 2nd edition, K N Liou, (AP) 2002, ISBN-10: 0124514510 *
'Remote Sensing of the Lower Atmosphere', G L Stephens, (OUP) 1994, ISBN-10: 0195081889 *
'A First Course in Atmospheric Radiation', 2nd edition, G W Petty, (Sundog Publishing) 2006, ISBN-10: 0972903313 *
'Atmospheric Radiation', R L Goody and Y L Yung, (OUP) 1995, ISBN-10: 0195102916 *
'Atmospheric and Oceanic Fluid Dynamics', G Vallis, (CUP) 2006, ISBN-10: 0521849691
'Chemistry of Atmospheres', 3rd edition, R P Wayne, (OUP), 2000, ISBN-10: 019850375X
'The Martian Climate Revisited', P L Read and S R Lewis, (Springer-Praxis) 2004, ISBN-10: 354040743X
'Giant Planets of our Solar System', P G J Irwin, (Springer-Praxis) 2003, ISBN-10: 3540006818

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 **Moderations 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 co-ordinates 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^2 will 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

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.

Treatment of electrostatic problems by solution of Poisson's equation using separation of variables in Cartesian, cylindrical or spherical coordinate systems. Representation of curl-free magnetic fields by a magnetic scalar potential and applications.

Electromagnetic waves in free space. Derivation of expressions for the energy density and energy flux (Poynting vector) in an electromagnetic field. Radiation pressure. *[Non-examinable: Magnetic vector potential. Description of radiation fields from an electric dipole aerial and a magnetic dipole aerial.*

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: derivation of the Fresnel equations for the reflection and transmission coefficients from Maxwell's equations. The Brewster angle. Total internal reflection, the evanescent wave and its demonstration. The electromagnetic wave equation in a conductor: skin depth. Electromagnetic waves in a plasma; the plasma frequency. *[Non-examinable: Scattering , dispersion and absorption of electromagnetic waves, treated in terms of the response of a damped classical harmonic oscillator.*

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. 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.

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 3-hour paper, divided into two sections
Answer 2 questions from 4 in each section offered; with each question worth 25 marks.

B1: I. Flows, Fluctuations and Complexity, and II. Symmetry and Relativity

Each section is 1.5 hour in duration and has four questions.
Answer two questions in each section offered.

I. Flows, fluctuations and complexity

Fluxes and conservation principles. Phase-space and Liouville's theorem. Deterministic and stochastic systems.

The Navier-Stokes equation, mass conservation. 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. Convective instability, Rayleigh-Bénard convection.

Flows in phase space, fixed points, stability, attractors, bifurcations. Lorenz system as a simple model of Rayleigh-Bénard convection, strange attractor, aperiodicity and predictability in simple chaotic systems. Fractals, Lyapunov exponents.

Simple stochastic processes, Einstein's theory of Brownian motion as an example of the fluctuation-dissipation theorem. Molecular diffusion. Fully developed turbulence, simple Kolmogorov theory, 2-d and 3-d turbulence.

Biomolecular machinery as examples of stochastic processes. The Nernst equation, biological free energy (including proton motive force, ATP synthesis and hydrolysis). The reaction-diffusion equation applied to molecular machines. Self-assembly and self-organisation of biological systems including membranes, DNA, RNA, proteins. Single-molecule measurements on biological molecular motors.

II. 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, general solution of Maxwell's equations using retarded potentials.

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 attenna; synchrotron radiation.

3-d and 4-d tensors; angular momentum and helicity; the Maxwell field tensor $F^{\mu\nu}$; Lorentz transformation of tensors with application to **E** and **B**. Energy-momentum tensor of the electromagnetic field, simple applications (e.g. ideal capacitor, solenoid, plane wave or similar).

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

B2: III. Quantum, Atomic and Molecular Physics, and IV. Sub-Atomic Physics

Each section is 1.5 hour in duration and has four questions.
Answer two questions in each section offered.

III. Quantum, atomic and molecular physics

Einstein A&B coefficients. Semi-classical treatment of two-level system: rate equation limit, Rabi oscillations and Bloch sphere. Decaying states and Lorentzian lineshape.

Classical uncertainty in quantum mechanics: pure and impure states. The density matrix and trace rule. Time-evolution of the density matrix. Measurement and loss of coherence.

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, spectroscopic notation. Selection rules for electric dipole radiation. X-rays. Magnetic dipole hyperfine structure; weak and strong magnetic field phenomena in both fine and hyperfine structure;.

Basic ideas of molecular physics, Born-Oppenheimer approximation, vibrational and rotational motion. Molecular spectra, Franck-Condon principle. *[Non-examinable: Simple ideas of molecular bonding, effects of exchange symmetry in homonuclear diatomic molecules.]*

Homogeneous and inhomogeneous broadening of spectral lines. Saturated absorption and saturated gain. Minimum conditions for laser operation, population inversion, the optical gain cross-section, rate equations governing population inversion and growth of laser radiation; cavity effects. 3- and 4-level laser systems. Frequency tuning of lasers.

IV. 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.

Basic ideas of detectors. 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.

Energy production through fission (nuclear reactors), fusion (p-p and D-T) in the Sun and Tokamaks. The p-p & CNO cycles. Solar neutrinos. Stellar structure; formation of heavier elements.

Quark model of hadrons: symmetries and evidence for quarks; nucleons as bound states of quarks; 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; decay of the neutron and parity violation. Production and decay of the W and Z bosons; the width of the Z and the number of neutrino types; neutrino oscillation.

B3: V. General Relativity and Cosmology, and VI. Condensed-Matter Physics

Each section is 1.5 hour in duration and has four questions.
Answer two questions in each section offered.

V: 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.

Experimental tests of General Relativity: planetary probes; Hulse-Taylor pulsar; emission lines from accretion discs.

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 and deceleration.

Thermal history of the universe. Saha's equation and the CMB; decoupling between photons and baryons; observations; non-equilibrium n/p abundance, freeze out and the formation of the light elements.

VI: Condensed-matter physics

Free electron model of metals, Fermi energy and Fermi surface. Drude theory, conductivity and Hall effect (one carrier only).

Lattice vibrations: law of Dulong and Petit; phonons; dispersion relation with two atomic types: acoustic and optical branches; Einstein and Debye models of heat capacity.

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

Crystals. Bravais lattices, lattice planes, Miller indices and unit cells (conventional and primitive). Reciprocal lattice: Bragg and Laue formulation of diffraction; Brillouin zone; neutron and x-ray scattering.

Electrons in periodic potentials; tight binding model; band structure; Fermi surface; semiconductors and insulators. Semiconductors: Doping; law of mass action; direct and indirect band gap; concepts of holes and effective mass; mobility and Hall effect in semiconductor *[Non examinable: p-n junction, MOSFET]*.

Magnetism: *[Non examinable: Hund's rules]*, Para- dia-, ferro-, antiferro-, and ferrimagnetism. Local Moment vs Itinerant magnetism. Mean field theory. Domains, domain motion, hysteresis

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 28.*

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 Solar system and Kepler's Laws. Extra-solar planets. The Sun and the basics of stellar structure. A qualitative view of star formation, stellar evolution and the synthesis of heavy elements. Non-interacting binary systems and the masses of stars. Interacting binary systems. Black holes. Galaxies. Clusters of galaxies. The evidence for dark matter, including gravitational lensing. The expansion and origin of the Universe.

[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. Schrödinger's equation and boundary conditions. Solution for a particle in an infinite potential well, to obtain discrete energy levels and wavefunctions.

S04: Energy Studies

Historical development of power generation, global issues.

Conservation laws. Application of thermodynamic reasoning to power generation. Physical principles of thermal power plant.

Generation from mechanical sources (hydro, tidal, wave, wind), Solar energy (PV and solar thermal), Biomass, Nuclear fission reactors. Fusion power. Energy storage.

Risk assessment. Environmental and economic issues. Future trends.

S07: Classical Mechanics*

Calculus of variations: Euler--Lagrange equation, variation subject to constraints.
Lagrangian mechanics: principle of least action; generalized co-ordinates. 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; Liouville's theorem; principle of least action (again); Poisson brackets; symmetries and conservation laws; canonical transformations; Hamilton-Jacobi equation.
* also for the Physics and Philosophy paper **BT:VII. Classical Mechanics**

S09: Financial Physics

An introduction to the physics-based approach to finance theory (so-called 'Econophysics'). This interdisciplinary field aims to apply ideas and mathematical techniques developed in physics (particularly those related to statistical mechanics) to improve our understanding of the empirically observed fluctuations in global financial markets. Emphasis is placed on the extent to which asset prices deviate from random walk behaviour, the development of microscopic models which may help to explain these deviations, and the minimization or *hedging* of financial risk.

S12: Introduction to Biological Physics

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

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

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

S16: Plasma Physics

Debye Length. Plasma frequency. The plasma parameter. Single particle motion: Larmor orbits, guiding centre drift. First adiabatic invariant. Analysis of subset of electrostatic and electromagnetic waves in unmagnetized and magnetized cold plasmas. Bohm Gross frequency, ion acoustic waves. The Coulomb logarithm. The Vlasov equation and Landau damping (integration in the complex plane not required). The equations of ideal Magnetohydrodynamics. The Lawson criterion. Simple concepts of magnetic confinement fusion. Simple concepts of inertial confinement fusion. Inverse bremsstrahlung absorption. Qualitative understanding of stimulated Raman and Brillouin scattering. Applications to astrophysics: Faraday rotation and conversion; evidence for large scale B-fields. Qualitative discussion of Parker instability and star formation. Simple description of Fermi acceleration.

S18: Advanced Quantum Mechanics

Introduction to scattering theory: scattering by a potential; the differential cross-section; stationary states and the scattering amplitude; calculation of the cross section using probability currents.

Integral scattering equation: definition of the Green Function**;** the Lipmann- Schwinger equation; determination of the Green function (**r** and **k** space); Born Series; calculation of the Born approximation for a Yukawa potential. Operator formalism of the Lippmann-Schwinger equation; determination of the Green function (regularisation in the complex plane); the Born Series in operator notation

Scattering by a central potential: method of partial waves; angular momentum stationary states; expansion of a plane wave in terms of free spherical waves; partial waves in a central potential; definition of a phase shift; expression of the cross section in terms of the phase shifts; unitarity and the optical theorem.

The Klein-Gordon equation: identification of probability density; 4-vector formulation; historical perspective – the problem of the negative energy and probability states; Pauli-Weisskopf reinterpretation of the probability density and Feynman-Stuckelberg interpretation of the negative energy states.

The relativistic treatment of scattering: Lorentz invariant form of the electromagnetic potential; the scattering amplitude and current density; the propagator of the Klein-Gordon equation; the determination of the scattering amplitude.

The Dirac equation: Dirac matrices and the relativistic generalisation of the Schrodinger equation; Dirac's derivation – the "square root" of the Schrodinger equation; hole theory interpretation; free particle solutions. Introduction of electromagnetism; coupled equations for the upper and lower spinor components; the non-relativistic limit; gyromagnetic ratio. Symmetries: angular momentum, spin and helicity; parity.

S19: Particle Accelerator Science

History of particle accelerators. Maxwell's equation, movements of charged particles in an electromagnetic field. Particle sources (Guns). Particle acceleration (Linacs and RF). Beam optics (Overview, Lattices, ...) Liouville's theorem and the concept of emittance. Beam dynamics, imperfections, resonnances. Space charges and instabilities. Instrumentation, beam diagnostics and feedbacks. Applications of particle accelerators in High Energy Physics and outside HEP.

S25: Physics of Climate Change

This course outlines the basic physics underlying our understanding of the climate system's response to external drivers such as increasing greenhouse gas levels on timescales of decades to centuries. We cover: the distinction between weather and climate in a chaotic system; planetary energy balance; atmospheric temperature structure; the greenhouse effect; forcing, feedbacks and climate sensitivity; the role of the oceans in the transient climate response; the global carbon cycle; simple box-diffusion models of global climate change; evidence for human influence on climate; impacts on the hydrological cycle; and prospects and risks of geo-engineering.

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.

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,
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 B2.III 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 (B2:IV) and the symmetry & relativity (B1:II) 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 +

The subjects of the Preliminary Examination in Physics shall be physics, including basic practical and mathematical techniques. The number of papers and other general requirements of the Preliminary Examination in Physics shall be prescribed by regulation from time to time by the Board of the Division of Mathematical, Physical and Life Sciences.

A

1. The subjects 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 prescribed by regulation from time to time by the Board of the Division of Mathematical and Physical Sciences.

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: *Physics2*

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 cl. 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 cl. 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 cl. 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 cl. 1, offer one or two papers, the Moderators shall publish the names only of 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 cl. 1 at a single examination and in the requirements of cl. 2.

6. 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.

7. The list of Short Option subjects in cl. 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 cl. 2(ii) a candidate may propose to the Chairman of the 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 *Special Regulations concerning 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* - 'The Grey Book') each academic year.

SPECIAL 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) The examination in physics shall consist of respectively three parts for the four-year course (A, B, C) and two parts for the three-year course (A, B) as prescribed in the regulation by the Mathematical, Physical and Life Science Board.

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 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. 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 in the final year of the four-year course, who has satisfied the requirements for Part A and Part B of the four-year course, but who does not enter Part C, may supplicate for the degree of Bachelor of Arts in Physics (pass or classified as appropriate), subject to the requirement to undertake and report on a project either in the form of an extended essay on a subject approved by the Chairman of the Faculty of Physics or his/her deputy, or an account of extended practical work, so that it is equivalent to that required for the three-year course; 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 passed or been exempted from the First Public Examination.

5. The Examination in Physics shall be under the supervision of the Board of the Division of Mathematical Physical and Life Sciences. The board shall have power, subject to these decrees, from time to time to frame and to vary regulations for the different parts and subjects of the 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 Special Regulations concerning 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.

PHYSICS (four year course)

1. 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.

2. 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. **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. 3(a)(ii).

4. **In Part B**

(a) the candidate shall be required

(i) to offer three 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 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. 4(a)(ii).

5. The titles of the written papers of cl. 3(a)(i) & cl. 4(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.

6. The list of Short Option subjects in cls 3(a)(iii), 3(b), 4(a)(iii), 4(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.

7. In cl. 4(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 Chairman of the Faculty of Physics or deputy, by the end of Michaelmas Full Term.

8. With respect to cl. 3(a)(iii) or cl. 4(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 Chairman of the Faculty of Physics or deputy and by the Director of the Language Teaching 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.

9. With respect to subjects under cl. 3(a)(iii) or cl. 4(a)(iii) a candidate may propose to the Chairman of the 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. 3(a)(ii) or cl. 4(a)(ii). Candidates will be advised of the decision by the end of eighth week of that term.

10. 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.
(c) candidates may be examined by viva voce'

11. In cl. 10(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.

12. With respect to subjects under cl. 10(a) a candidate may propose to the Chairman of the 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.

13. In cl. 10(b), the proposed nature of the practical or other advanced work and its duration shall be submitted for approval to the Chairman of the Faculty of Physics or deputy with the agreement of the Physics Academic Committee.

Schedule

Fundamental Principles (Part A)
A1: *Thermal Physics*
A2: *Electromagnetism and Optics*
A3: *Quantum Physics*

Physics (Part B)
B1: *I. Flows, Fluctuations and Complexity*, and *II. Symmetry and Relativity*
B2: *III. Quantum, Atomic and Molecular Physics*, and *IV. Sub-Atomic Physics*
B3: *V. General Relativity and Cosmology*, and *VI. Condensed-Matter Physics*

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*

PHYSICS (three year course)

1. 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. **Part A** of the examination shall be the same as the Part A of the examination of the four-year course in Physics and the same conditions, arrangements and examination timings shall apply.

3. In **Part B**

(a) the candidate shall be required
(i) to offer four** of the subjects I-VI specified for papers B1 to B3 in the Schedule of the four-year course (Part B), each subject having the weight of half a paper, and
(ii) to submit to the Examiners such evidence as they require of the successful completion of practical work normally pursued during one and a half terms in the academic year of the examination, and
(iii) to offer a written paper on one Short Option.
(b) to offer a project report in the form of either an extended essay on a subject approved by the Chairman of the Faculty of Physics or deputy (by the end of sixth week of Hilary Full Term), or an account of extended practical work undertaken in the academic year in which the examination takes place.

4. With respect to cl. 3(a)(ii) a candidate may offer instead a written paper on a second Short Option.

5. The Short Options of cl. 3(a)(iii) and cl. 5 are those specified in cl. 6 of the four-year course.

6. In cl. 3(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 Chairman of the Faculty of Physics or deputy, by the end of Michaelmas Full Term.

7. With respect to cl. 3(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 Chairman of the 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.

8. With respect to subjects under cl. 3(a)(iii) a candidate may propose to the Chairman of the 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.

[+] **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* - 'The Grey Book') and the *Universiy Gazette* each academic year.

**these must include sections III, IV and VI

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/rso/integrity/ip.shtml these explain the approved arrangements for revenue-sharing. Further information may be obtained from Research Services, University Offices (tel. (2)70143).

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, but, save as may be separately agreed between the University Press and the person concerned, works commissioned by the University Press in the course of its publishing business shall not be regarded as 'works commissioned by the University'.
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.

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Practicalities

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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...

Appendix M

Academic Staff Telephone Numbers, College Affiliations and e-mail

(College telephone numbers are for the College Lodge, and numbers for the sub-Department are for the Departmental receptionist)
All staff in the Department can be contacted by e-mail. The general form of address is:
a.other@physics.ox.ac.uk
(If there are two or more people in the Department with the same name, they would be distinguished by a number eg. *a.other2@physics.ox.ac.uk*)

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