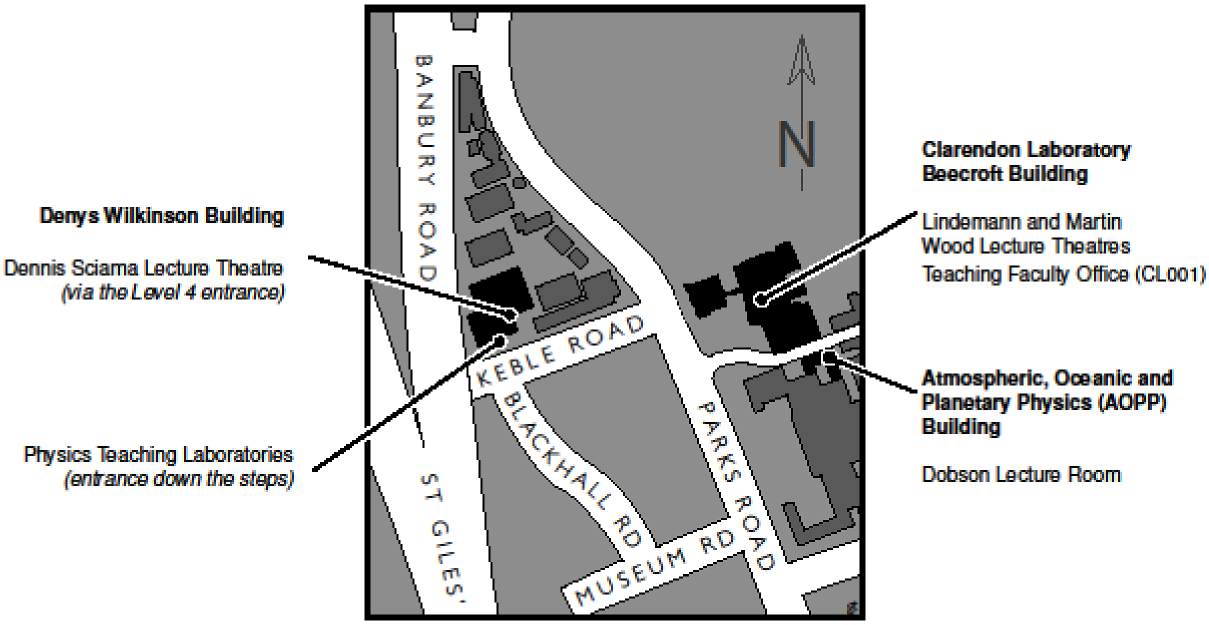
Physics Undergraduate Course Handbook 2020-2021

Fourth Year (Part C)

UNIVERSITY OF OXFORD

Map of the Department of Physics Buildings



Useful Department Contacts

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

These notes have been produced by the **Department of Physics**. The information in this handbook is for the academic year Michaelmas Term 2020, Hilary Term 2021 and Trinity Term 2021.

Contents

Coronavirus (Covid)

The University publishes updates at https://www.ox.ac.uk/coronavirus. Adaptations to the physics undergraduate course, made necessary due to Coronavirus (Covid) derive from the university guidelines and are laid out within the lectures and practical course arrangements.

Introduction to the handbook

A handbook is provided for each year of the programme and it is also useful to read the handbooks on topics available in earlier years. This handbook contains, amongst other things, a comprehensive book/reading list, also available via ORLO (Oxford Reading List Online); important dates for the academic year; information about the undergraduate consultative committee (PJCC); and a list of people involved in organising the course. Please read this handbook thoroughly and refer to it frequently, as it will often contain the answers to many common questions.

Other useful sources of information:

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

Further information about the courses can be obtained from the Department of Physics website http://www2.physics.ox.ac.uk/students/undergraduates and from the Physics Teaching Office.

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

For full and up-to-date information on lecture timetables.

The examination times given in this handbook are based on information available in September 2020. These may be altered and the definitive times are those published by the examiners; these will be posted on the official examiners' page.

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

The information in this handbook is accurate as at **5 October 2020**, however it may be necessary for changes to be made in certain circumstances, as explained at http://www2.physics.ox.ac.uk/students/undergraduates. If such changes are made the department will publish a new version of this handbook together with a list of the changes and students will be informed.

Important dates and deadlines

Michaelmas Term	Event	Time	Location
Week 0	Deadline for Major Option Choices		
Week 1	Project Safety for MPhys students	***	***
Week 7	MPhys project progress report		Online
Week 8	Entry for Part C	Fri	*

Trinity Term	Event	Time	Location
Week 1	Hand in MPhys projects	Mon 12:00	Online Submission
Week 4	Year Group meeting		***
Week 7	Part C examination		**

* Students submit their entries via their College Office and Student Self Service.
** See https://www.ox.ac.uk/students/academic/exams/timetables for the exam timetables.
*** See http://www.physics.ox.ac.uk/lectures/ for lecture details.

Introduction to the Department of Physics

The Department of Physics

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

Policies and Regulations

The University has a wide range of policies and regulations that apply to students. These are easily accessible through the A-Z of University regulations, codes of conduct and policies available on the Oxford Students website www.ox.ac.uk/students/academic/regulations/a-z. In particular, see the Policy on recording lectures by students (located at: http://www.admin.ox.ac.uk/edc/policiesandguidance)

Data Protection

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

University Policy on Intellectual Property Rights

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

Copyright

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

Good academic practice and avoiding plagiarism

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

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

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

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

Support for disabled students

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

Student Life, Support and Guidance

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

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

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

Complaints and appeals

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

Opportunities to provide evaluation and feedback

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

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

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

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

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

Enterprise and entrepreneurship

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

The Institute of Physics

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

Fourth Year 2020-2021

Aims and Objectives

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

Major Options

In Trinity Term, you are required to take two Major Option papers of your choice (see **Appendix C**). 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 **no later than Friday of 0th week of Michaelmas.**

Lectures and Classes

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

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

The Major Options available are:

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

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

Alternative Major Options

It is possible to substitute another subject in place of a Physics Major Option, provided the course and exam already exist and are of sufficient weight.

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

Projects

Projects are carried out during Michaelmas and Hilary Terms. **There is a compulsory Safety Lecture in 1st week of Michaelmas Term, which all MPhys students must attend – this year it will be done remotely.**

MPhys Project Guidance published at http://www2.physics.ox.ac.uk/students/undergraduates/mphys-projects will contain a timetable for carrying out the project work and handing in the report.

The final report is submitted online by Monday of 1st week of Trinity Term. See the *MPhys Project Guidance* for more details.

Textbooks

A list of the books recommended by the lecturers is given in **Appendix A** and is also available via ORLO (Oxford Reading List Online). Major Option coordinators may advise you as to additional reading material.

Academic Progress

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

Fourth Year Patterns of Teaching

Timetable

The full Physics Undergraduate Lecture Timetable will show you when lectures are scheduled for all years.

Course structure

Two Papers from C1, C2, C3, C4, C5, C6, C7 and an MPhys Project Report

Each physics Major Option is normally supported by 8 classes. Typically a class size is 8 students. As a guide, about 10 hours of independent study is expected for each hour of tutorial or class teaching.

Paper		**Faculty Teaching**	
	Term	**Lectures**	**Classes**
C1. Astrophysics	MT	16	3
	HT	17	3
	TT	8	2
C2. Laser Science and Quantum Information Processing	MT	18	3
	HT	16	3
	TT	8	2
C3. Condensed Matter Physics	MT	20	3
	HT	7	3
	TT	13	2
C4. Particle Physics	MT	19	3
	HT	16	3
	TT	8	2
C5. Physics of Atmospheres and Oceans	MT	21	3
	HT	16	2
	TT	7	2
C6. Theoretical Physics	MT	24	3
	HT	16	3
	TT		2
C7. Biological Physics	MT	24	3
	HT	10	3
	TT	8	2
Additional lectures	MT	1	
	HT	1	
	TT	1	

Physics Examinations

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

Examination Entry

Entry for the FHS Part C exam is at the end of 8th week of Michaelmas Term.

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

Examination Dates

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

Examination Regulations

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

Examination Conventions

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

The Academic Committee is responsible for the detailed weightings of papers and projects. The definitive version will be published not less than one whole term before the examination takes place. The precise details of how the final marks are calculated are published on the official examiners' page.

Examination Preparation

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

Past Exam Papers

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

External Examiner and Examiners' Reports

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

Sitting your examination

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

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

Part C Examination

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

Physics	Physics and Philosophy
Two papers from C1, C2, C3, C4, C5, C6, C7 MPhys Project Report	The details depend on the option route See the *Physics and Philosophy* Handbook

Assessment of Class

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

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

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

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

Examination Results

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

If you are unhappy with an aspect of your assessment you may make a complaint or academic appeal (see https://www.ox.ac.uk/students/academic/complaints

Year Outcome for Part C

The examiners will classify students at the end of the MPhys course according to using the University's USM scale

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

Part C Examination Prizes

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

- Scott prizes
- Gibbs prizes
- Project prizes

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

Physics and Philosophy

The fourth year comprises Part C of the FHS. The examinations are 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 Physics and in the *MPhys Project Guidance* published at http://www2.physics.ox.ac.uk/students/undergraduates/mphys-projects . Syllabuses for the Physics Major Options are given in **Appendix C**.

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 about project allocation etc., and most importantly: There is a compulsory Safety Lecture in 1st week of Michaelmas Term – this year it will be done remotely if you intend to do an experimental project**.**

Appendix A Recommended Textbooks – Fourth Year

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

<u>Fourth Year</u>

C1. Astrophysics

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

C2. Laser Science and Quantum Information Processing

Quantum Information

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

Laser Science and Modern Optics

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

Quantum Optics

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

C3. Condensed Matter Physics

General texts

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

Individual topics

● *Structure & Dynamics*

'Structure and Dynamics', M T Dove (OUP, 2003) **

'The Basics of Crystallography and Diffraction', C Hammond (OUP, 2001) *

'Fundamentals of Crystallography', C Giacovazzo, H L Monaco, G Artioli, D Viterbo, G Ferraris, G Gilli, G Zanotti and M Catti (OUP, 2002) *

● *Electronic Properties*

'Band Theory and Electronic Properties of Solids', J Singleton (OUP, 2001) **

● *Optical Properties*

'Optical Properties of Solids', A M Fox (OUP, 2001) **

● *Magnetism*

'Magnetism in Condensed Matter', S J Blundell (OUP, 2000) **

'Theory of Magnetism', K Yosida (Springer, 1996) *

● *Superconductivity*

'Superconductivity, Superfluids and Condensates', J F Annett, (OUP, 2004) **

'Introduction to Superconductivity', M Tinkham, (McGraw-Hill, 1996) *

'Superconductivity: A Very Short Introduction', S J Blundell (OUP, 2009) *

C4. Particle Physics

Introductory

'Particle Physics', B R Martin & G P Shaw (Wiley (3rd Ed))

Course Text:

'Particle Physics in the LHC Era', G.Barr, R. Devenish, R. Walczak, T. Weidberg (OUP 2016)**

Other textbooks at the appropriate level:

'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)) *

'Femtophysics', M G Bowler (Pergamon)

More advanced:

'Introduction to Elementary Particles', M Griffiths (Wiley (2nd Ed)) *

'Modern Particle Physics', M. Thomson (CUP) *

References

(Most are graduate level texts)

'Experimental foundations of Particle Physics', R Cahn & G Goldhaber (CUP (2nd Ed))

'An Introduction to the Standard Model of Part. Phys.', Cottingham & Greenwood (CUP (2nd Ed))

'Quarks & Leptons', F Halzen & A D Martin (Wiley)

'Deep Inelastic Scattering', Devenish & Cooper-Sarkar (OUP)

'Particle Astrophysics', D H Perkins (OUP (2nd Ed))

RQM

'Relativistic Quantum Mechanics', P Strange (CUP)

'Relativistic Quantum Mechanics', I J R Aitchison (Macmillan)

'Quantum Mechanics II', R H Landau (Wiley)

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

C5. Physics of Atmospheres and Oceans
General Texts
'An Introduction to Atmospheric Physics', D. G. Andrews, (2nd Ed, CUP, 2010)
'Atmospheric Science', J. M. Wallace & P. V. Hobbs (Academic Press, 2006)
Radiation and Thermodynamics
'Principles of Planetary Climate', R. T. Pierrehumbert (CUP, 2010)
'Atmospheric Radiation', R. L. Goody and Y. L. Yung (OUP, 1995)
Clouds and Aerosols
'Concepts in Thermal Physics', S. J. Blundell abd K. M. Blundell (OUP, 2006)
'An Introduction to Clouds', U. Lohmann et al (CUP, 2016)
Instruments
'Elementary Climate Physics', F. W. Taylor (OUP, 2009)
Geophysical Fluid Dynamics
'Essentials of Atmospheric and Oceanic Dynamics', G. Vallis (2020)
'Fluid Dynamics of the Mid-Latitude Atmosphere', B. J. Hoskins and I. James (Wiley-Blackwell, 2014)
'An Introduction to Dynamic Meteorology', Holton
'Atmosphere, Ocean and Climate Dynamics', Marshall and Plumb (Academic Press, 2008)
'Atmospheric and Oceanic Fluid Dynamics', G. Vallis (2nd Ed, CUP, 2017)

C6. Theoretical Physics
Part I (MT)
'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 **
'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) *
'Principles of Condensed Matter Physics', P. M. Chaikin and T. C. Lubensky (CUP) *
'Introduction to Gauge Field Theory', D. Bailin and A. Love, mainly chapters 1 – 6 *
'Quantum Mechanics and Path Integrals', R. P. Feynman and A. R. Hibbs (McGraw-Hill) *

Part II (HT)
'Introduction to Gauge Field Theory', D. Bailin and A. Love, mainly chapters 1 – 6 **
'Quantum Field Theory in a Nutshell', A. Zee, Part I *
'An Introduction to Quantum Field Theory', M. V. Peskin and D. V. Schroeder (Addison-Wesley) **
'Aspects of Symmetry', S. Coleman (Cambridge University Press) *

‘Solitons and Instantons’, R. Rajaraman (North-Holland) *
‘Digestible Quantum Field Theory’, A. Smilga (Springer) *

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) *
'Physics of the Life Sciences', Jay Newman (Springer)
'Physical Biology of the Cell'. 2nd Edition, Phillips, Kondev, Theriot & Garcia (Garland Science)

## Appendix B		Note on Calculators for ALL Public Examinations*

The regulations are likely to follow recent practice which is:

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

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

Notes:

These guidelines follow closely the regulations on the ‘Use of calculators in Examinations’ in the University *Examination Regulations* (‘The Grey Book’) and https://examregs.admin.ox.ac.uk/. The exact requirements in a given year will be published by the Examiners.

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

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

Appendix C Syllabuses for the Fourth Year (Final Honour School – 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 6 with each question worth 25 marks.

C1. Astrophysics

Radiative processes in astrophysics – radiative transfer theory; formation and analysis of emission and absorption lines; ionisation balance; cosmic dust and extinction. Application to planetary nebulae, stars, the interstellar and the intergalactic medium.

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

Advanced stellar astrophysics and galaxies – Star formation and evolution. Composite stellar populations in galaxies. The Milky Way and other galaxies: properties, formation and evolution.

Cosmology — current cosmological models; anisotropies in the Cosmic Microwave Background; large scale structure; gravitational lensing.

C2. Laser Science and Quantum Information Processing

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

Lasers:

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

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

C2. Laser Science and Quantum Information Processing Cont'd

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.

Amplitude and phase modulation of light using the linear electro-optic effect. Second harmonic generation. 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. Local realism, EPR, the four Bell states, the Bell inequalities, GHZ states.

Quantum Computation:

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

Quantum Communication:

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

C3. Condensed Matter Physics

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

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

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

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

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

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

C4. Particle Physics

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

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

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

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

Electroweak interactions, charged and neutral currents. Electroweak symmetry breaking. W and Z bosons. Fundamental particles of the Standard Model. Discovery of the top quark. The Standard Model Higgs mechanism and discovery of 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 and Clouds

Composition and structure of Earth and planetary atmospheres. Dry thermodynamics: hydrostatic equation, lapse rate, potential temperature, entropy. Moist thermodynamics: Clausius-Clapeyron equation, phase diagrams, moist adiabat, cloud formation. Convection: buoyancy, parcel theory, atmospheric stability, thermodynamic diagrams, potential energy, quasi-equilibrium hypothesis. Cloud microphysics. Cloud morphology and occurrence. Planetary and exoplanetary clouds.

Radiative transfer and radiative forcing

Radiative transfer in atmospheres: Black body radiation, Emission spectrum of Earth and other planets, the solar and stellar spectra, the total solar irradiance. Molecular spectra, line shape and line intensity. Schwartzschild equation for non-scattering atmospheres. Band models. Pure radiative equilibrium and radiative-convective equilibrium. Radiative properties of clouds and aerosols. Rayleigh & Mie scattering. Radiative forcing by greenhouse gases and aerosols. Climate sensitivity. Instrumentation for radiation measurement and remote sensing of temperature and atmospheric constituents.

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. Overview of large-scale structure and circulation of atmospheres and oceans, poleward heat transport. Angular momentum and Held-Hou model of Hadley circulations. Applications to Mars and slowly-rotating planets. Tide-locked exoplanets. Giant planets: Multiple jets, stable eddies and free modes.

Climate dynamics and predictability

Time-dependent error-growth in chaotic systems; implications for weather analysis, forecasting and predictability. Random processes as models of atmosphere/ocean behaviour. Collective behaviour of the atmosphere-ocean system arising from coupling of radiative, thermodynamic and fluid dynamical processes. Applications to understanding natural and human-induced climate change.

Observations

Discussion of observations of Earth and planetary atmospheres and of the Earth's oceans is integrated into the treatment of the fundamental physical phenomena on which they have a bearing.

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 equations 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.

Appendix D Complaints and Appeals

Complaints and academic appeals within the Department of Physics

The University, the **MPLS Division** and **Department of Physics** all hope that provision made for students at all stages of their course of study will result in no need for complaints (about that provision) or appeals (against the outcomes of any form of assessment).

Where such a need arises, an informal discussion with the person immediately responsible for the issue that you wish to complain about (and who may not be one of the individuals identified below) is often the simplest way to achieve a satisfactory resolution.

Many sources of advice are available from colleges, faculties/departments and bodies like the Counselling Service or the OUSU Student Advice Service, which have extensive experience in advising students. You may wish to take advice from one of those sources before pursuing your complaint.

General areas of concern about provision affecting students as a whole should be raised through Joint Consultative Committees or via student representation on the faculty/department's committees.

Complaints

If your concern or complaint relates to teaching or other provision made by the **Department of Physics**, then you should raise it with the Head of Teaching, **Prof Hans Kraus**. Complaints about departmental facilities should be made to the Head of Administration. If you feel unable to approach one of those individuals, you may contact the Head of Department, **Prof Ian Shipsey**. The officer concerned will attempt to resolve your concern/complaint informally.

If you are dissatisfied with the outcome, you may take your concern further by making a formal complaint to the Proctors under the University Student Complaints Procedure (https://www.ox.ac.uk/students/academic/complaints).

If your concern or complaint relates to teaching or other provision made by your college, you should raise it either with your tutor or with one of the college officers, Senior Tutor, Tutor for Graduates (as appropriate). Your college will also be able to explain how to take your complaint further if you are dissatisfied with the outcome of its consideration.

Academic appeals

An academic appeal is an appeal against the decision of an academic body (e.g. boards of examiners, transfer and confirmation decisions etc.), on grounds such as procedural error or evidence of bias. There is no right of appeal against academic judgement.

If you have any concerns about your assessment process or outcome it is advisable to discuss these first informally with your subject or college tutor, Senior Tutor, course director, director of studies, supervisor or college or departmental administrator as appropriate. They will be able to explain the assessment process that was undertaken and may be able to address your concerns. Queries must not be raised directly with the examiners.

If you still have concerns you can make a formal appeal to the Proctors who will consider appeals under the University Academic Appeals Procedure (https://www.ox.ac.uk/students/academic/complaints).